UNIVERSIDADE DE LISBOA

Lisbon School of Economics & Management

THREE ESSAYS ON PUBLIC INVESTMENT VERSUS PRIVATE INVESTMENT

Inácia Carvalho Dias Ferreira Pimentel Pacheco Pereira

Orientador: Prof. Doutor Miguel St. Aubyn

Tese especialmente elaborada para obtenção do grau de Doutor em Economia

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To my mother and my father for supporting me unconditionally.

To my dear husband Duarte, love of my life.

To my son Duarte and my daughter Francisca that make me happier every day.

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Abstract

The capacity of public consumption, public investment, and private investment to influence the economic activity has been a research topic for decades, however, there is no consensus about the qualitative effects of fiscal policy. The main goal of this dissertation is to deepen the understanding about what role public intervention, through PPPs, public consumption, and public investment, may play in boosting economic activity and to compare it with the results from innovations in private investment.

In the first essay the macroeconomic impact of investment in PPPs, public and private investment in Portugal was tested using a VAR model. The results show that public and private investment has a positive effect in GDP while investment in PPP reduces the Portuguese output. Moreover, an increase in PPP investment crowds-out both private and public investment, while public investment presents a crowding-in effect in both private investment and investment in PPP; and private investment shows the same crowding-in effect in both investment in PPP and public investment. In the second essay, a VAR was applied to a panel data for 14 OECD countries to investigate the dynamic impact of public consumption, public investment, and private investment on the average output of these countries. We find that public consumption plays an active role only in those economies which suffered severe economic consequences in the recent crisis. On the contrary, private investment allows a boost in the output of all the countries under analysis. Finally, in the third essay, a GVAR approach was used to test for the cross-country spillover effects of an increase in public and private investment in 16 countries. The findings show statistically significant cross-border effects mainly in neighboring countries, with the magnitude of the impacts being modest.

Key words: Key words: Investment, Crowding-in/out, VAR, PVAR, GVAR

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Chapter 1

Introduction

The capacity of public consumption, public investment, and private investment to influence economic activity has been a research topic for decades. In fact, in advanced economies an increase in public investment is one of the few remaining policies available to push economic growth, and in developing economies an increase in infrastructure investment will allow the much needed expansion of these countries' productive capacity.

A large body of empirical literature has been investigating the impact of public capital on the private sector and on the economy as a whole. However, there is no consensus about the qualitative effects of fiscal policy: the integration properties of the variables, the fact that production functions are estimated with differenced data, or if pooled regressions carried out with fixed effects can heavily influence the results, Dreger and Reimers (2014). As pointed out by Perotti (2007), so far the literature has not been able to provide robust stylized facts on the effects of fiscal policy shocks. While Keynesian economists predict an increase in private consumption and investment and, consequently, a boost in economic performance following an innovation on government spending, neoclassicals argue that after a positive shock to government consumption there will be a withdrawal of resources from the private sector that is expected to reduce private consumption and investment.

From a theoretical perspective, an increase in public investment can have two opposite effects on private investment, e.g. Aschauer (1989b) and Mittnik and Neumann (2000). On the one hand, an increase in public investment needs to be financed. If public and private sectors compete, at least partially, for the same resources, the costs for private investment will rise, causing a decrease in private investment, thereby leading to a crowding-out effect. Conversely, in a crowding-in scenario, an increase in public investment can create more favorable conditions for private sector investment, especially through the development of facilities that can increase private capital productivity.

One way to finance public investment is through Public Private Partnerships (PPP). It is well known that in the 1980s and 1990s an extensive privatization program took place in the countries of Western Europe. These privatizations were based on the idea that the private sector shows higher efficiency standards in the management of companies in comparison to public management. However, some reservations remained about the private sector's capacity to ensure the management of natural monopolies and large infrastructure with high sunk costs more efficiently than the public sector. In the latter case, PPP imposed itself, more recently, as an alternative method for financing investment projects traditionally funded by taxation and executed in the sphere of public sector.

Against this background, the main goal of this dissertation is to deepen the understanding about what role public intervention, through PPPs, public consumption, and public investment, may play in boosting economic activity and to compare it with the results from innovations in private investment. In fact, in an economic environment such as the European Monetary Union (EMU), in which fiscal policy is the only instrument that governments have to offset idiosyncratic shocks, it is crucial to determine the capacity of public consumption and public investment to influence the economic activity of a country. Moreover, the recovery of the euro area over the last decade has been slow, weak, and uneven. After the 2007-2008 crisis some euro area countries accumulated large and persistent current account deficits, while other member states presented high and persistent surpluses. This situation leads to questioning the role of current account surplus countries in the European economy recovery.

To investigate these questions we use three different econometric methodologies. First, we use of a VAR-model technology. This type of model makes it possible to identify a shock to a variable, which is an innovation that may occur independently from other variables. It also has the advantage of allowing the evaluation of the dynamic effects of all variables in the analysis and overcomes the issue of endogeneity of the regressors. Next, we use a panel VAR in which, as in a VAR, all variables are treated as endogenous and interdependent. However, the panel VAR approach allows for unobserved individual heterogeneity, adding a cross sectional dimension to the model. In fact, the dynamic interdependencies, the static interdependences, and the cross sectional interdependencies distinguish the panel VARs typically used in macroeconomics and financial analyses from the initial work of Holtz Eakin, et al. (1988), in which interdependencies were disregarded and sectoral homogeneity was assumed. As put by Canova and Ciccarelli (2013) "a panel VAR is similar to large scale VARs where dynamic and statistic interdependencies are allowed for. It differs because cross sectional

heterogeneity imposes a structure on the covariance matrix of the error terms." In this case, annual data were used instead of quarterly observations, as there is no quarterly calendar for fiscal policy, and for that reason shocks identified with annual data may be closer actual shocks. The main drawback of annual data is the exclusion of within-year responses to shocks and also the fact that fewer observations are available. Being so, to increase the precision of our estimates a panel VAR data was used. Moreover, this study relies on macroeconomic time series data alone for shock identification, not imposing any restriction of the responses of the key variables to shocks to public consumption, public investment, and private investment.

Last, we use a Global Vector Autoregressive (GVAR) modeling approach introduced by Pesaran, Schuermann, and Weiner (2004). This type of model combines individual country-specific models, in which domestic variables are related to country-specific foreign variables that match the relative importance of the rest of the world for the country under consideration, providing an effective way to deal with the curse of dimensionality. Though GVAR models are linear, they allow for a range of different interdependencies between variables and countries, such as theory consistent long-run relationships, short-run spillover effects, or cross-sectional dependence in the error structure. Thus, they offer a fair degree of flexibility in modeling business-cycle dynamics of the world economy in a coherent fashion. In the cases of both the VAR and the Panel VAR approach, the impacts of the shocks were analyzed taking into account the results from the Impulse Response Functions (IRF) and Variance Decomposition. In a GVAR context of multi-countries and several variables, General Impulse Response Functions (GIRFs) are preferable to the standard IRFs proposed by Sims (1980), which assume orthogonal shocks. It is known that if IRFs are calculated using different orders of variables, then the shape of the IRFs will be different. In fact, if the model is estimated using a reduced number of variables, a relationship between the variables can be inferred based on economic theory. However, this approach is not valid for the GVAR model since it typically contains a large number of variables. Moreover, traditional IRFs are difficult to use in a GVAR since there is no realistic way to order the countries in the model.

This dissertation comprises three essays on the relationship between public and private investment based on macroeconomic evidence.

The first essay was written in co-authorship with Miguel St. Aubyn and Nuno Ribeiro and tests the macroeconomic impact of investment in PPPs, public and private investment in Portugal, through a VAR model with four variables: public investment, private investment, PPP investment, and GDP, for the period 1998-2013. The focus on Portugal is due to

two main reasons. First, Portugal is the European country that between 1990 and 2009 spent the highest amount of money in PPP as a percentage of its GDP (10.55%), representing 7% of the value expended in European PPPs and being the third largest PPP market by value in Europe, as can be seem in Table 2.7 and Figure 2.4. Second, the Economic Adjustment Programme for Portugal demanded a study of the impact in the country's economy of the investment made in PPPs:

> *The annual review of PPPs and concessions will be accompanied by an analysis of credit flows channelled to PPPs through banks (loans and securities other than shares) by industry and an impact assessment on credit allocation and crowding out effects. This particular element will be done in liaison with the Bank of Portugal. , in European Economy, Occasional Papers, June 2011, page 70.*

Being so, an assessment of crowding-in/crowding-out effects of investment in PPPs is carried out.

We also calculate the macroeconomic rates of return on investment in PPP, public investment, and private investment seeking to quantify the impact of each of these components of investment in GDP. In fact, from a macroeconomic point of view, it is important to have a criterion for assessing the desirability of the investment financed through PPPs, in contrast to public investment and private investment. To date, studies about PPP are very polarized between those in favor and those against PPP, have been mainly of a microeconomic nature, and come to very different conclusions. Pollit (2002) write that *"in a sample of ten major PFI case evaluations undertaken, the best deal was probably obtained in every case, and good value for money was probably achieved in eight of the ten cases."*. On the contrary, Pollock, Shaoul, and Vickers (2002), Monbiot (2002), Bloomfield, Westerling, and Carey (1998), Greve (2003), and Walker and Walker (2000) studied PPPs in the United Kingdom, United States, Europe, and Australia, respectively and were unanimous in concluding that PPP were not the best option if VfM is taken into account. Presently, the *focus* of investigation related to PPP has been changing. In fact, a new purpose is to understand the reasons why governments choose PPPs for investment in public infrastructures (Greve and Hodge 2008).

The main novelty of our paper is the use of a VAR-model technology applied to investment in PPPs with four variables: PPP investment, public investment, private investment and GDP. As mentioned above, this type of model allows us to identify a shock to a variable, an independent innovation, with the advantages of allowing the evaluation of dynamic effects and of overcoming the endogeneity issue. The results show that public and private investment has a positive effect in GDP while investment in

PPP reduces the Portuguese GDP. Regarding the crowding-in/crowding-out effects, an increase in PPP investment crowds-out both private and public investment, while public investment presents a crowding-in effect in both private investment and investment in PPP; and private investment shows the same crowding-in effect in both investment in PPP and public investment.

The second essay seeks to provide evidence on the effects of selected key macroeconomic variables to shocks to public consumption, public investment, and private investment for two distinct groups of countries that were formed according to their capacity to refinance their government debt or to bail out over-indebted banks on their own during the recent crisis of 2008-2014. Although so far the literature has been unable to provide robust stylized facts on the effects of fiscal policy shocks, it is a fact that VAR shocks to government spending seem to be associated with a rise in output. For instances, using a mixed structural VAR/event approach, Blanchard and Perotti (2002) concluded that positive government spending shocks have a positive effect on output, on hours, consumption, and real wages. Follow-up work, such as Galí, López-Salido and Vallés (2007) extended the standard new Keynesian model to allow for the presence of rule-of-thumb consumers, showing that consumption rises as a consequence to a shock in government spending. In turn, Fatas and Mihov (2002) found strong evidence in favor of the hypothesis that large governments reduce the volatility of both private and total output. However, Mountford and Uhlig (2005) and Edelberg et al. (1999) provide evidence that the response of private consumption is close to zero and not statistically significant over the entire horizon of the impulse response. Linnemann (2005) questioned if there is really a mismatch between business cycle theories and the evidence, showing that the evidence can be explained by a standard real business cycle type model. In this study, a VAR was applied to a panel data for 14 OECD countries to investigate the dynamic impact of public consumption, public investment, and private investment on the average output of these countries.

Relying on macroeconomic time series data alone for shock identification, from the results of the Impulse Response Functions and Variance Decomposition, we find that countries do not react in the same way to an impulse in public consumption, public investment and private investment. In fact, public consumption plays an active role only in those economies which suffered severe economic consequences in the recent crisis. On the contrary, private investment allows a boost in the output of all the countries under analysis. This paper relies on macroeconomic time series data alone for shock identification, thereby not imposing any restriction of the responses of the key variables to shocks to public consumption, public investment, and private investment.

Finally, in the third essay, written in co-authorship with Miguel St. Aubyn and Paulo Rodrigues, a GVAR approach was used to test for the cross-country spillover effects of an increase in public and private investment in 16 countries. The impact of these innovations in a central European economy (Germany) and in a peripheral one (Portugal) on the majority of the European countries, USA, and Japan were examined and quantified by employing GIRFs. The GVAR framework has been applied to various fields, such as the role of credit and credit risk diversification, which were two of the subjects; see for instance Dees, di Mauro, Pesaran, and Smith (2006), Eickmeier and Ng (2011), Xu (2012), or Pesaran, Schuermann, and Treutler (2006). Monetary union membership counterfactual scenarios were presented by Pesaran, Smith and Smith (2007) and by Dubois, Hericourt, and Mignon (2009). Cashin, Mohaddes, Raissi, and Raissi (2012) employed a set of sign restrictions on the generalized impulse responses of a GVAR model to distinguish supply-driven from demand-driven oil price shocks and to study the time profile of their macroeconomic effects in different countries. Chudik and Fidora (2012) also explored the subject of supply shocks using a GVAR model.

Inflation was another topic analyzed applying a GVAR; for details check Galesi and Lombardi (2009). Anderton, Galesi, Lombardi, and di Mauro (2010) calculated the impact of increased imports from low-cost countries on manufacturing import prices and estimated Phillips curves to explore whether the inflationary process in OECD countries changed over time. The US role as a potentially globally dominant economy was investigated by Dées and Saint-Guilhem (2011). Chudik and Smith (2013) extended the literature on the role of a globally dominant economy, once again the US, by comparing two models: one that treats the US as a globally dominant economy, and a standard version of a GVAR model that does not separate the impact of the US variables from the cross-section average of foreign economies, as in Dées, di Mauro, Pesaran, and Smith (2007). From a global imbalances perspective, Bettendorf (2012) showed that real GDP is a relatively unimportant variable compared to real exchange and interest rates and to the oil price, and also provides a counterfactual analysis of the US trade balance. Bussière, Chudik, and Sestieri (2012) studied the effects of demand shocks and shocks to relative prices on global imbalances. To the best of our knowledge the GVAR approach has not yet been used to test for cross-border spillover effects of an increase in public and private investment in the Euro area. Overall, we find that even if Germany increases its public investment, it will not have the desired positive impact on peripheral economies. The findings show statistically significant cross-border effects mainly in neighboring countries, with the magnitude of the impacts being modest

The three essays were written in such a way that they can be read separately. For this reason, there is some overlap between chapters regarding the background information.

Chapter 2

The impact of investment in Public Private Partnerships on Public, Private Investment, and GDP in Portugal

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2.1. Introduction

In the 1980s and 1990s an extensive privatization program took place in the countries of Western Europe. These privatizations were motivated by the idea that the private sector shows higher efficiency standards in the management of companies in comparison to public management. However, there remained some reservations about the private sector's capacity to ensure the management of natural monopolies and large infrastructure with high sunk costs more efficiently than the public sector. In the latter case, Public-Private Partnerships (PPP) became popular, more recently, as alternatives to the traditional way of financing investment projects through taxation and execution in the public sector sphere.

This paper studies the impact of investment in Public Private Partnerships on public and private investment and GDP in Portugal. The focus on Portugal is due to two main reasons: Portugal is the European country that between 1990 and 2009, spent the greatest amount of money in PPP as a percentage of its GDP (10.55%), representing 7% of the value expended in European PPPs and being the third largest PPP market by value in Europe (see Table 2.7. and Figure 2.4. in the Appendix); and the memorandum

of understanding for Portugal demanded a study of the impact in the country's economy of the investment made in PPPs.

Our assessment of crowding-in/crowding-out effects of investment in PPPs is therefore undertaken. We calculate macroeconomic rates of return on investment in PPP, public investment, and private investment, seeking to quantify the impact of each of these components of investment in GDP.

Macroeconomic theory suggests that an increase in investment in PPPs in public investment can have two opposite effects on private investment (Aschauer 1989b, and Mittnik and Neumann 2000). On the one hand, an increase in public investment in PPPs is partly funded in the capital markets, which would lead to a reduction in the funds available to private investors and to an increase in interest rates charged by lenders. This would lead to a decrease in the rate of return on private investment, thus causing crowding-out of this. Conversely, an increase in public investment in PPPs can create more favorable conditions for investment by the private sector, especially through the development of road infrastructure, railway, airports, among others. In this case, there is crowding-in in private investment.

From a macroeconomic point of view, it is important to have a criterion for assessing the desirability of the investment financed through PPPs, in contrast to public investment and private investment.

The main novelty of this paper is the use of a VAR-model technology applied to investment in PPPs with four variables: PPP investment, public investment, private investment, and GDP. This type of model allows us to identify a shock to a variable, which is an independent innovation that may occur in other variables. It also has the advantage of allowing the evaluation of the dynamic effects of all variables in the analysis and overcoming the issue of endogeneity of the regressors.

The rest of this chapter is organized as follows. Section 2.2 briefly reviews general literature about PPP and studies that have applied a VAR approach to study the impact of public and private investment on the economy. Section 2.3 describes the econometric methodology underlying our empirical application, namely, VAR specifications, macroeconomic rates of return, and the computation of crowding-in and crowding-out effects. Section 2.4 discusses the empirical results of this study. Section 2.5 summarizes the main findings, and, finally, the Appendix provides information on the list of concessions used to calculate the PPP investment.

2.2. Literature Review

Studies about PPP are very polarized between those in favor and those against PPP.

The term PPP has been used more frequently in the literature since the 1990s.

> *The public-private partnerships (PPP) phenomenon has been with us for a long time. The phrase first became used by a specialist audience in the 1970s, and books were being written about such partnerships even in the 1980s (e.g. Rose, 1986), although it was the 1990s before it was widely recognized, when the Private Finance Initiative was launched by the John Major administration in the UK, and the acronyms 'PPP' became common currency. However, the actual phenomenon goes much further back into history.* (Bovaird 2010).

It is used to refer to different types of contracts between the public and private sector. (Argy 1999).

However there is some consensus concerning the key elements of a PPP. As can be found in Commission of the European Communities (2004), the main elements that characterize a PPP are:

> *(…) the relatively long duration of the relationship, involving cooperation between the public partner and the private partner (…); (…)the method of funding the Project, in part from the private sector, sometimes by means of complex arrangements between the various players(…); (…)the distribution of risks between the public partner and private partner(…).*

Other definitions can be found in Van Ham and Koppenjan (2001) and Lossa and Martimort (2008).

Broadbent and Laughlin (1999) were pioneers in this field of investigation, raising five main questions for the study of PPPs in England, namely:

*Is PFI a form of privatisation of the public sector? What is the nature of PFI and who is regulating its application? How are definitions of PFI in terms of value for money and risk transfer derived and operationalised? How are PFI decisions made in different areas of the public sector and what are the effects of these decisions? What is the merit and worth of PFI?*The question of *value for money* (VfM) has been largely discussed concerning PPPs. Hodge and Greve (2008) argue that:

> *Value for Money is a purposely vague concept and one designed to reorient the language of debate away from traditional concerns such as choosing the "cheapest" competitive construction bid which meets the public interest, towards discussion of whole-of-life costs, risk transfers and risk-adjusted discounted rates for specific large projects.*

The studies carried out to evaluate PPPs performance have been until now mainly of a microeconomic nature and come to very different conclusions. Pollit (2002) says that *"in a sample of ten major PFI case evaluations undertaken, the best deal was probably*

obtained in every case, and good value for money was probably achieved in eight of the ten cases." Pollock, Shaoul, and Vickers (2002), Monbiot (2002), Bloomfield, Westerling, and Carey (1998), Greve (2003), and Walker and Walker (2000) studied PPPs in the United Kingdom, United States, Europe, and Australia, respectively and were unanimous in concluding that PPP where not the best option if VfM is taken into account.

Also concerning econometric studies related to PPPs, Hammami, Ruhashyankiko, and Yehoue (2006) carried out a first attempt *"to analyze the determinants of PPPs in infrastructure projects using the World Bank's Private Participation in Infrastructure (PPI) database on projects for developing countries during 1990-2003".*

Presently, the *focus* of investigation related to PPP has been changing. In fact, a new purpose is to understand the reasons why governments choose PPPs to investment in public infrastructures. *"In other words, our renewed agenda items should tackle why governments choose to introduce PPP despite the fact that projects can be financed through traditional methods"* Greve and Hodge (2008). In 1996 Terry said that *"Private financing promised a way to provide infrastructure without increasing the public sector borrowing ratio."* Hodge (2002) calls the attention to the fact that the duration of a PPP can cover more than one parliamentary term and Flinders (2005) argues that *"Governments continue to display such an apparently blind commitment to PPPs."*.

More recently Greve and Hodge (2008) up dated the study carried by Broadbent and Laughlin (1999). In their opinion the most relevant questions related to PPPs are:

1. *What is the merit/worth of PPPs?*
2. *In what circumstances do PPPs provide an effective and efficient tool for governments in terms of simply VfM [value for money] and innovation?*
3. *In what circumstances do PPPs provide governments with a successful governance tool to overcome traditional governance failures?*
4. *How can PPPs be best regulated in the public interest in the future?*
5. *What role to date have Auditors General undertaken in PPP evaluation, and how might we meta-summarize their assessment to date?*
6. *Why and how are PPPs promoted in some jurisdictions and not in others?*
7. *What is the nature and consequence of a global "PPP industry"?*
8. *What is the place of PPPs in development activities?*
9. *What is the next chapter for PPPs and what are the implications?*

This paper analyzes the investment in PPP in a macroeconomic perspective since it studies the aggregated effects of investment in PPP in other macroeconomic aggregates, such as, public investment, private investment, and GDP. An assessment of crowding-in/crowding-out effects of investment in PPPs is carried out and macroeconomic rates of return on investment in PPP, public investment, and private investment were calculated and aimed at quantifying the impact of each of these components of investment in GDP.

In fact, since Aschauer's work (1989a, 1989b) there has been interest in analyzing the effects of public investment on aggregate economic activity and also to investigate whether public investment crowds-in/crowds-out private investment.

Voss (2002) and Mittnik and Neaumann (2001) estimated the effects of public investment on GDP and the crowding-in/crowding-out effects using a VAR approach. Voss (2002) estimated a VAR model with GDP, public investment, private investment, the real interest rate, and deflators of private and public investment for the US and Canada for the period of 1947-1997 and concluded that public investment crowds-out private investment. Mittnik and Neaumann (2001) used a VAR model with GDP, private investment, public investment, and public consumption for six industrialized economies. They concluded that public investment tends to exert positive effects on GDP, and that there is no evidence of crowding-out effects.

Pereira and Andraz (2005) used data for Portugal between 1976 and 1998 using a VAR-model considering private-sector output, employment, investment, and public investment. Empirical results at the aggregate level indicate that public investment positively affects private investment, employment, and output.

More recently, Afonso and St. Aubyn (2009), using annual data from 14 European Union countries, Canada, Japan, and the United States evaluated the macroeconomic effects of public and private investment with a VAR analysis. The results point to the existence of positive effects of public investment and private investment on output. On the other hand, the crowding-in effect of public investment on private investment varies across countries, while the crowding-in effects of private investment on public investment are more generalized.

2.3. Econometric Methodology

2.3.1 VAR specification

A four variable VAR model was estimated. The variables included in the VAR are the logarithmic growth rates of real Public Private Partnerships investment (IPPP), real public investment (IPub), real private investment (IPriv), and real output (Y).The list of concessions used to calculate the PPP investment can be seen in Table 2.8 of the Appendix. Public investment was calculated by the difference between the Gross Fixed Capital Formation series (GFCF) from Public Administration and the investment from reclassified PPP as belonging to Public Administration. Regarding private investment, it results from the difference between the GFCF made by the private sector and the investment from the non-reclassified PPP.

The VAR model can be presented as:

$$X_t = c + \sum_{i=1}^{p} A_i X_{t-1} + \varepsilon_t \quad (1)$$

where X_t denotes the (4x1) vector of four endogenous variables given by $X_t = [\Delta logIPPP_t \;\; \Delta logIPub_t \;\; \Delta logIPriv_t \;\; \Delta logY_t\,]$, c is a (4x1) vector of intercept terms, A is the matrix of autoregressive coefficients of order (4x4), and $\varepsilon_t = \left[\varepsilon_t^{Ippp} \;\; \varepsilon_t^{Ipub} \;\; \varepsilon_t^{Ipriv} \;\; \varepsilon_t^{Y}\right]$ is a vector of random disturbances that contains the reduced form OLS residuals.

It is possible to identify orthogonal shocks, η, for each variable in (1), by imposing a set of restrictions, and to compute these orthogonal innovations via the random disturbances:

$$\eta_t = B\varepsilon_t \quad (2)$$

The estimation of (1) allows the determination of $Cov(\varepsilon)$. Therefore, with orthogonal restrictions and by means of an adequate normalization, we have $Cov(\eta) = I$, where $I = (4X4)$ identity matrix , and we can write:

$$Cov(\eta_t) = Cov(B\varepsilon_t) = BCov(\varepsilon_t)B' \quad (3)$$

$$I = BCov(\varepsilon_t)B' \quad (4)$$

B has 16 parameters that need to be identified, since B is a square (nXn) matrix, which in this case has dimension four. From (4) only 12 parameters can be determined, by imposing orthogonality, essentially from the four variances and from the eight covariances. Four more restrictions are needed for the complete identification of the model. The use of a Choleski decomposition of the matrix of covariances of the residuals, which requires all elements above the principal diagonal to be zero, provides the necessary additional six restrictions, and the system is then exactly identified.

A lower triangular structure to B^{-1}can be imposed,

$$B^{-1} = D = \begin{bmatrix} d_{11} & 0 & 0 & 0 \\ d_{21} & d_{22} & 0 & 0 \\ d_{31} & d_{32} & d_{33} & 0 \\ d_{41} & d_{42} & d_{43} & d_{44} \end{bmatrix} \quad (5)$$

which makes it possible to write the residuals ε_t as a function of the orthogonal shocks in each of the variables:

$$\varepsilon_t = D\eta_t$$

The variables in the VAR were ordered from what is theoretically considered the most exogenous variable to the least exogenous one, with PPP investment ordered first, followed by public investment, private investment, and output. Being so, a shock in PPP investment may have an instantaneous effect on all of the other variables. However, PPP investment does not respond contemporaneously to structural disturbances in the other variables. A shock in public investment, the second variable, does not have an instantaneous impact on PPP investment, only on private investment and output. In fact, this ordering implies that private investment responds to PPP and public investment in a contemporaneous way, but not to shocks to the other variables. Indeed, one can recall that governments typically announce their spending and investment plans in advance. Therefore, economic agents can incorporate this information in their decisions.

2.3.2 Macroeconomic rates of return

Six different rates of return were computed based on the results from impulse response functions:

- the partial rate of return of investment in PPP;
- the partial rate of return of public investment;
- the partial rate of return of private investment;
- the rate of return of total investment deriving from an impulse to PPP investment;
- the rate of return of total investment deriving from an impulse to public investment;
- the rate of return of total investment deriving from an impulse to private investment;

The partial rate of return of investment in PPP is computed as in Pereira (2000). Following an orthogonal impulse to investment in PPP the long-run accumulated elasticity of *Y* with respect to investment in PPP*, IPPP,* was computed deriving from the accumulated impulse response functions of the VAR:

$$\varepsilon_{IPPP} = \frac{\Delta logY}{\Delta log\ IPPP}$$

This long-run elasticity is the ratio between the accumulated change in the growth rate of output and the accumulated change in the growth rate of PPP investment.

It is known that:

$$\frac{\Delta Y}{\Delta IPPP} = \varepsilon_{IPPP} \frac{\bar{Y}}{\overline{IPPP}}$$

Being so, the partial rate of return of investment in PPP is obtained by solving:

$$(1 + r)^{20} = \frac{\Delta Y}{\Delta IPPP}$$

Note that it is not possible to decompose the variation of the product that is due separately to a change in investment in PPP and the consequent change in public

investment and/or private investment. Thus, the isolated reading of the partial rate of return can bias the analysis of the total impact in the product of a variation of investment in PPP. We used 20 years to compute both rates of return, as we assumed an average life of 20 years for a capital good.

The partial rates of return of public and private investment were computed using the same technology mentioned above.

Following Pina and St. Aubyn (2006) the rate of return of total investment deriving from an impulse to PPP investment was obtained as a solution for:

$$(1+r)^{20} = \frac{\Delta Y}{\Delta IPPP + \Delta IPub + \Delta IPriv} =$$

$$= \frac{1}{\left(\varepsilon_{IPPP}\frac{Y}{IPPP}\right)^{-1} + \left(\varepsilon_{IPub}\frac{Y}{IPub}\right)^{-1} + \left(\varepsilon_{IPriv}\frac{Y}{IPriv}\right)^{-1}}$$

That is, following a shock in investment in PPP, both the direct impact of this shock and the indirect impact through changes taking place in public and private investment that result from this shock in PPP investment, are taken into account.

The rate of return of total investment deriving from an impulse to public and private and investment was computed using the same technology mentioned above.

2.3.3 Crowding-in and crowding-out effects

The marginal effects of PPP investment on public investment and private investment were derived, respectively, from:

$$\frac{\Delta Ipub}{\Delta IPPP} = \frac{\varepsilon_{IPPP}}{\varepsilon_{Ipub}}\frac{\overline{Ipub}}{\overline{IPPP}}$$

and

$$\frac{\Delta Ipriv}{\Delta IPPP} = \frac{\varepsilon_{IPPP}}{\varepsilon_{Ipriv}}\frac{\overline{Iprıv}}{\overline{IPPP}}$$

In this way it is possible to check for the existence of crowding-in or crowding-out effects of PPP investment on public and private investment. These same effects were computed, following the same technology, for changes on public and private investment.

2.4. Empirical Results

2.4.1 Data

Annual data from 1998 to 2013 were used for the Portuguese economy. All variables are presented at constant prices. GDP was transformed into real values using the price deflator of GDP. The price deflator of the general government gross fixed capital formation was used to transform both the investment in PPP and the public investment into real values, and the price deflator of the gross fixed capital formation of the private sector to transform private investment. The data sources for the investment in PPP are UTAP, Brisa, and INE.

2.4.2 VAR estimation

All variables used in the VAR are in logarithmic growth rates and in first differences of the original values. The unit root analysis showed that these first differenced variables are stationary, I(0) time series. Table 2.1 summarizes the results for the unit root test statistics.

Table 2.1. Unit root tests, variables in first differences: Augmented Dickey-Fuller

	Augmented Dickey-Fuller	
	t-Statistic	Critical value
dlog (Y)	-5.5407	-2.7406
dlog(IPPP)	-2.9548	-2.7406
dlog(Ipub)	-2.8271	-2.7406
dlog(Ipriv)	-4.8176	-2.7406

Note: critical values are for 1% level. No tendency or interception was adopted.

The Akaike and the Schwartz information criteria were used to select the VAR order used in the estimation. Taking into account the length of the data used in the VAR and those tests, a parsimonious model with only one lag was chosen in order to avoid the use of too many degrees of freedom. The null hypothesis of normality of the VAR residuals was not rejected. The diagnostic tests for normality are presented in Table 2.2. For a *p-value*

of 5% the null hypothesis of no serial correlation of the residuals cannot be rejected as can be seen in Table 2.2.

Table 2.2 Residual normality tests

Component	Skewness	Chi-sq	df	Prob.
1	1.222453	3.486915	1	0.0619
2	-0.072623	0.012306	1	0.9117
3	1.074501	2.693956	1	0.1007
4	-0.028190	0.001854	1	0.9657
Joint		6.195031	4	0.1850

Component	Kurtosis	Chi-sq	df	Prob.
1	4.036431	0.626610	1	0.4286
2	2.229281	0.346505	1	0.5561
3	4.694197	1.674344	1	0.1957
4	2.001411	0.581688	1	0.4457
Joint		3.229147	4	0.5202

Component	Jarque-Bera	Df	Prob.
1	4.113525	2	0.1279
2	0.358811	2	0.8358
3	4.368300	2	0.1126
4	0.583542	2	0.7469
Joint	9.424178	8	0.3078

2.4.3 Rates of return

The information on accumulated responses of all VAR variables to a shock in investment in PPP and in public and private investment is presented in Table 2.3. A 95 percent confidence band around estimates is also included and the figures in bold represent the cases in which those confidence bands include positive or negative values only. The conclusion is that impulses in investment in PPP have no statistically significant effects on the other variables at 95 percent level. On the other hand, impulses to private and public investment have a positive and significant impact on output.

Table 2.3. Accumulated responses to shocks in PPP and public and private investment

Accumulated responses of	Shock to investment in PPP			Shock to Public Investment			Shock to Private Investment		
	-2 S.E.	CENTRAL	+2 S.E	-2 S.E.	CENTRAL	+2 S.E	-2 S.E.	CENTRAL	+2 S.E
IPPP	**0.0675**	**0.3804**	**0.6933**	-0.0318	0.2513	0.5344	-0.1333	0.2914	0.7161
IPub	-0.1158	-0.0291	0.0576	**0.0627**	**0.1403**	**0.2179**	-0.0631	0.0507	0.1645
IPriv	-0.065	-0.0274	0.0102	-0.0116	0.0233	0.0582	**0.0499**	**0.0982**	**0.1465**
Y	-0.0158	0.001	0.0178	**0.0092**	**0.0245**	**0.0398**	**0.0182**	**0.0393**	**0.0604**

The results for the output elasticity and the partial and total rates of returns of an impulse in investment in PPP, public investment, and private investment, for the period in which data are available, are presented in Tables 2.9, 2.10, and 2.11, respectively, in the Appendix. These three types of investment present a positive output elasticity, with the output elasticity of private investment (0.3998) being higher than the output elasticity of public investment (0.1743) and investment in PPP (0.0026).

Both public and private investments present a positive partial and total rate of return, with the total rate of return of public investment (0.0491) greater than the total rate of return of private investment (0.0332). In the case of the investment in PPP, this rate of return cannot be calculated since its partial rate of return is negative.

2.4.4 Crowding-in and crowding-out effects

The results for the crowding-in and crowding-out effects for the investment in PPP, public investment, and private investment are presented in Tables 2.4, 2.5, and 2.6 respectively. $\varepsilon_{\mathrm{IPriv}}$

Table 2.4. Crowding-in or crowding-out effects resulting from an impulse in the investment in PPP

$\varepsilon_{\mathrm{IPriv}}$	-0.0365
$\varepsilon_{\mathrm{IPub}}$	-0.0344
$\varepsilon_{\mathrm{IPPP}}$	0.0026
$\overline{IPriv}$	29298.4375
$\overline{IPub}$	5217.2500
$\overline{IPPP}$	997.9375
Crowding-in or crowding-out effects resulting from an impulse in the investment in PPP	
ΔIPriv/ΔIPPP	**-2.1166**
ΔIPub/ΔIPPP	**-0.4005**

Investment in PPP presents a crowding-out effect in both public and private investment, with the magnitude of the crowding-out effect on private investment (-2.1166) greater than in public investment (-0.4005). On the other hand, public investment crowds-in in both private investment and investment in PPP, showing a greater impact in private investment (0.9317) than in investment in PPP (0.3425). Finally, private investment also shows *a* crowding-in effect in both investment in PPP and public investment, with the impact in the investment in PPP (0.1011) being slightly greater than in public investment (0.0918).

Table 2.5. Crowding-in or crowding-out effects resulting from an impulse in public investment

ε_{IPriv}	1.0507
ε_{IPub}	0.1743
ε_{IPPP}	0.0974
$\overline{IPriv}$	29298.4375
$\overline{IPub}$	5217.2500
$\overline{IPPP}$	997.9375
Crowding-in or crowding-out effects resulting from an impulse in public investment	
ΔIPriv/ΔIPub	0.9317
ΔIPPP/ΔIPub	0.3425

Table 2.6. Crowding-in or crowding-out effects resulting from an impulse in private investment

ε_{IPriv}	0.3998
ε_{IPub}	0.7755
ε_{IPPP}	0.1347
$\overline{IPriv}$	29298.4375
$\overline{IPub}$	5217.2500
$\overline{IPPP}$	997.9375
Crowding-in or crowding-out effects resulting from an impulse in private investment	
ΔIPPP/ΔIPriv	0.1011
ΔIPub/ΔIPriv	0.0918

2.5. Conclusions

Investment in PPP leads to a crowding-out effect in both private and public investment and has a negative impact on GDP. In fact, the partial rate of return of an investment in PPP is negative and the total rate of return associated with investment in PPP cannot be calculated since the accumulated gross growth rate in 20 years is negative.

Public investment presents a crowding-in effect in private investment and in investment in PPP. In fact, in the presence of a positive shock in public investment, the impulse response functions show a positive initial impact in both investment in PPP and GDP. The output elasticity of public investment is positive and statistically significant. The partial rate of return of public investment is greater than its total rate of return due to the fact that in the presence of a shock in public investment the response from the private investment and investment in PPP leads to an increase in output.

Finally, private investment crowds-in in both investment in PPP and in public investment. The output elasticity of private investment is positive and statistically significant. The partial rate of return of private investment is higher than its total rate of return taking into account that the response of both public investment and investment in PPP to a shock in public investment is positive.

The results that point to the existence of crowding-out in private and public investment as a consequence of investment in PPP, together with a negative partial rate of return of PPPs, are evidence that investment in PPP in Portugal, which involved almost exclusively the construction and operation of road infrastructures, is not the most efficient method of financing this kind of investment and/or have facilitated the expansion of road infrastructures beyond the social optimum. In fact, the investment through PPPs does not appear to be the kind of investment leading to the higher productivity that the Portuguese economy needs for a sustained increase in its export capacity and to allow for the correction of the accumulated external imbalances. Empirical results also support the belief that this kind of investment undermined the capacity of private agents and the public sector to carry out their investment activities.

These conclusions are obviously conditioned by the information used, to the concessions analyzed, and to the size of the sample used, the time period, and frequency. In fact, to estimate this VAR model, only 16 annual observations (1998-2013) are available. Using one constant, four variables, and one lag we estimate 5 parameters with only 14 observations. This equates to fewer than 3 observations per parameter. This number of observations is relatively small for drawing conclusions from the model with a high

degree of robustness. This small number of observations is also reflected in the impulse response functions shown in Figures 2.1, 2.2, and 2.3. In many cases the impulse response functions are statistically not different from zero.

Figure 2.1. Responses to shocks in PPP investment

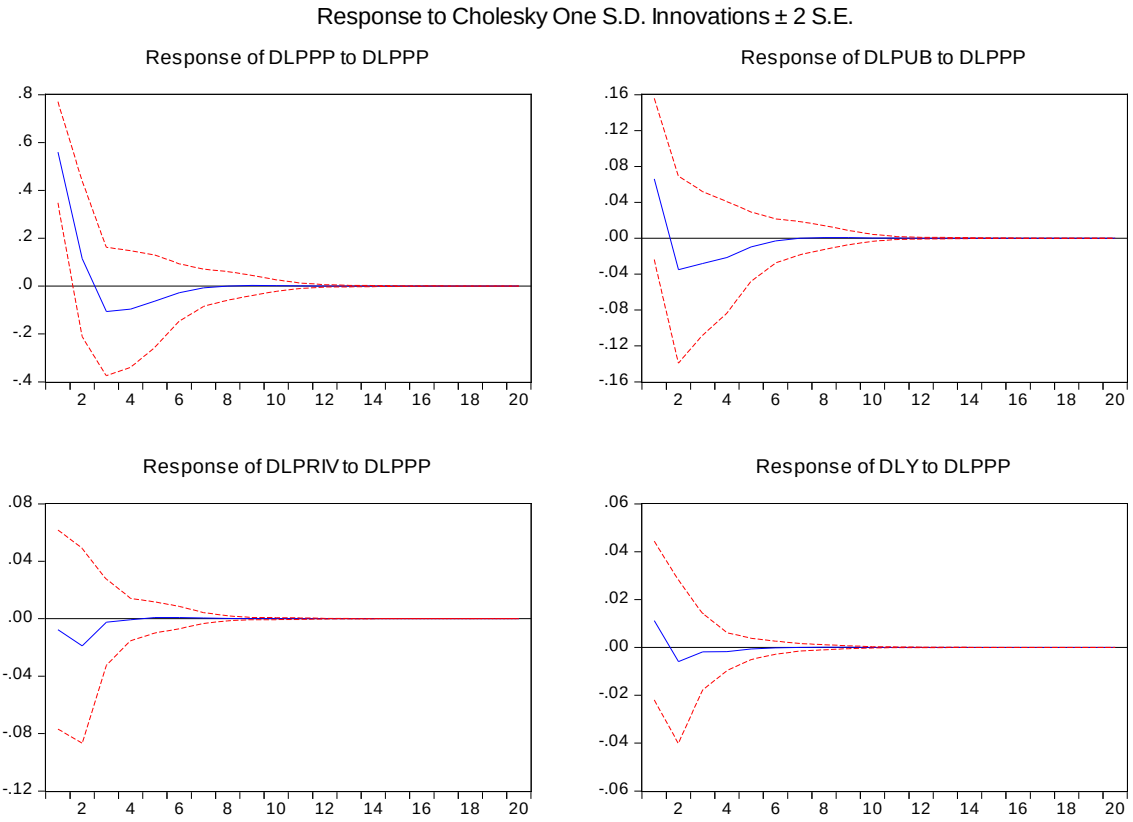


Figure 2.2. Responses to shocks in public investment

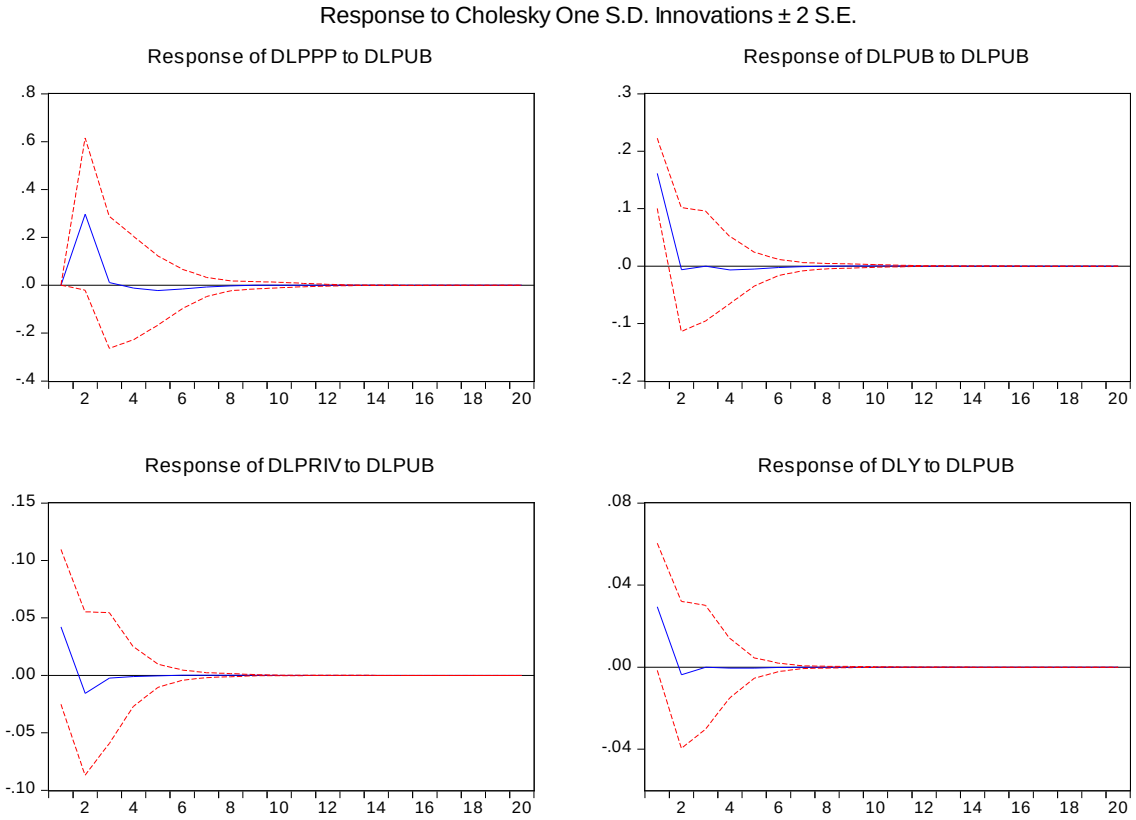
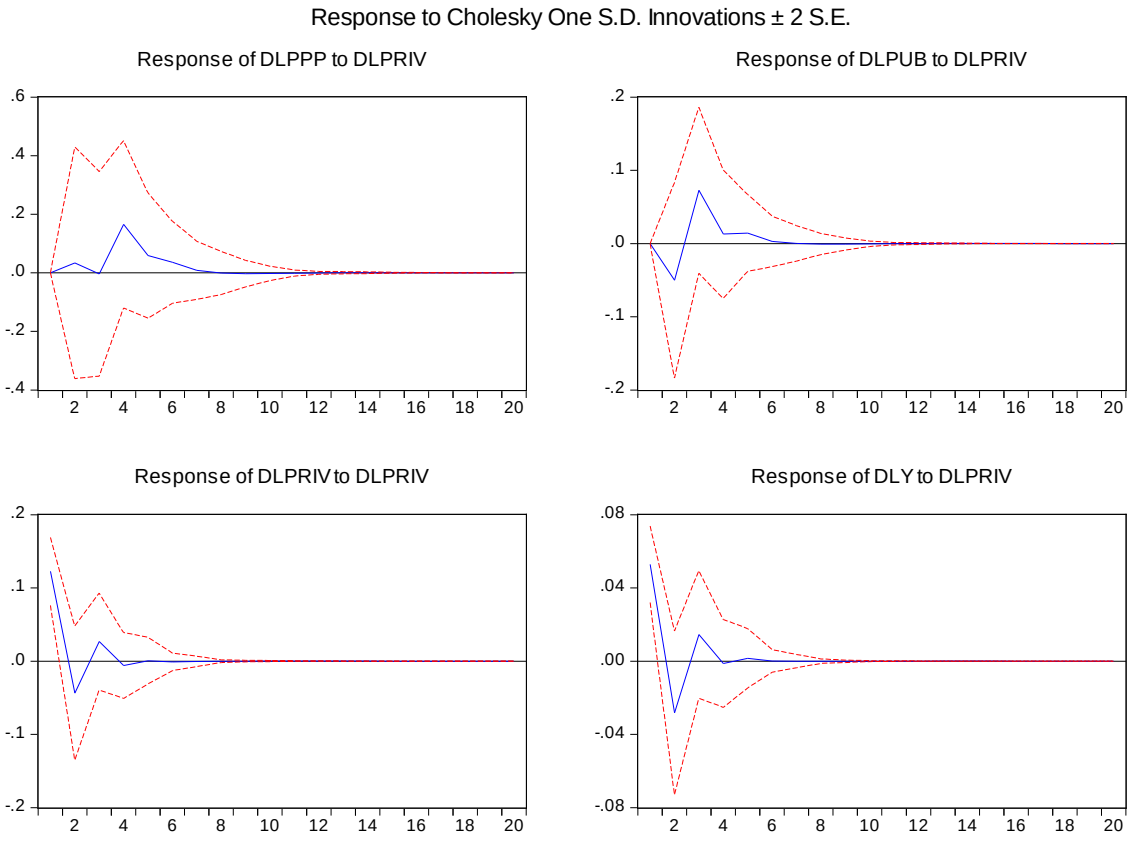


Figure 2.3. Responses to shocks in private investment



With respect to the VAR model, other specifications were tested that included variables such as the total amount of taxes at constant prices, the long-term interest rate, and the level of employment, revealing no impact on the final results.

2.6. Appendix

Table 2.7. Total amount of investment in PPP between 1990-2009 as a percentage of the 2009 GDP of each country

PT	10.55%
UK	8.38%
HU	6.39%
EL	6.05%
CY	4.52%
ES	2.77%
IE	2.5%
SK	2.02%
PL	1.39%
BE	0.97%
NL	0.8%
BG	0.73%
FR	0.71%
IT	0.55%
CZ	0.54%
AT	0.46%
DE	0.44%
FI	0.29%
SE	0.17%
DK	0%
LV	0%
MA	0%
RO	0%
SI	0%

Source: Kappeler and Nemoz (2010) and Eurostat

Table 2.8. List of concessions used to calculate the PPP investment

Concession
Road sector
Concessão Lusoponte
Concessão Norte
Concessão Oeste
Concessão Brisa
Concessão Litoral Centro
Concessão Beira Interior
Concessão Costa de Prata
Concessão Algarve
Concessão Interior Norte
Concessão Beiras Litoral e Alta
Concessão Norte Litoral
Concessão Grande Porto
Concessão Douro Litoral
Concessão Grande Lisboa
Concessão Túnel do Marão
Subconcessão Transmontana
Subconcessão Douro Interior
Subconcessão Baixo Alentejo
Subconcessão Baixo Tejo
Subconcessão Litoral Oeste
Subconcessão Algarve Litoral
Subconcessão Pinhal Interior
Healthcare sector
H. Braga - Gestão do Estabelecimento
H. Braga - Gestão do Edifício
H. Cascais - Gestão do Estabelecimento
H. Cascais - Gestão do Edifício
H. Loures - Gestão do Estabelecimento
H. Loures - Gestão do Edifício
H. V Franca - Gestão do Estabelecimento
H. V Franca - Gestão do Edifício
Rail sector
Metro Sul Tejo
Fertagus
Defense sector
SIRESP

Table 2.9. Partial and total rates of returns deriving from an impulse in investment in PPP

Impulse response functions acumulated results	
ΔlogY	0.0010
Δlog Ipriv	-0.0274
ΔlogIPub	-0.0291
Δlog IPPP	0.3804
ε_{IPriv}	-0.0365
ε_{IPub}	-0.0344
ε_{IPPP}	**0.0026**
$\bar{Y}/\overline{IPriv}$	5.5245
$\bar{Y}/\overline{IPub}$	33.7169
$\bar{Y}/\overline{IPPP}$	250.0058
ΔY/ΔIPriv	-0.2017
ΔY/ΔIPub	-1.1588
ΔY/ΔIPPP	0.6582
$\frac{\Delta Y}{\overline{\Delta IPPP + \Delta IPub + \Delta IPriv}}$	-0.2325
Rate of return	
Parcial rate of return	**-0.0207**
Total rate of return	**-**

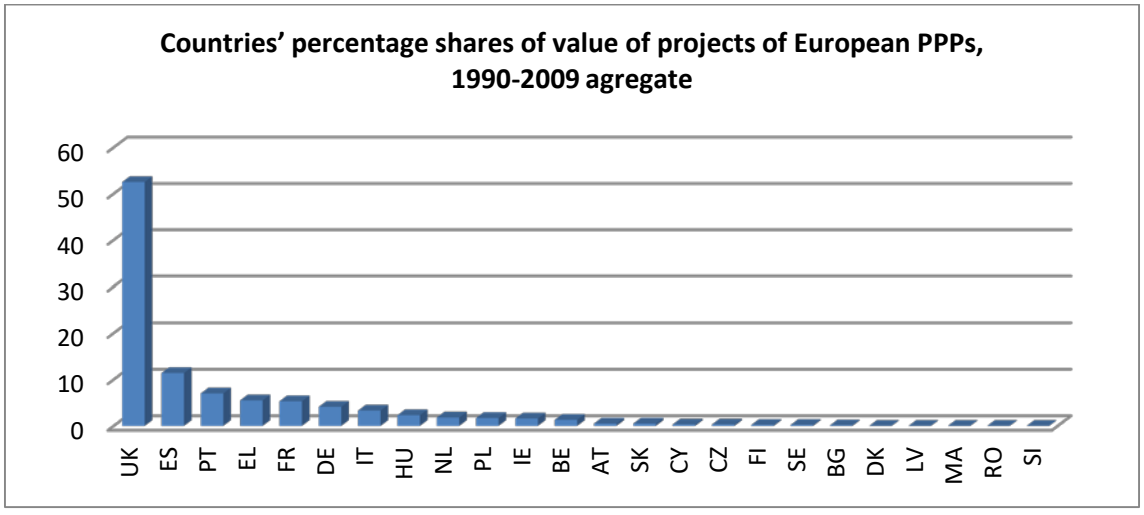
Table 2.10. Partial and total rates of returns deriving from an impulse in public investment

Impulse response functions acumulated results	
ΔlogY	0.0245
Δlog Ipriv	0.0233
Δlog Pub	0.1403
Δlog IPPP	0.2513
ε_{PPP}	1.0507
ε_{IPub}	**0.1743**
ε_{IPPP}	0.0974
$\bar{Y}/\overline{IPriv}$	5.5245
$\bar{Y}/\overline{IPub}$	33.7169
$\bar{Y}/\overline{IPPP}$	250.0058
ΔY/ΔIPriv	5.8047
ΔY/ΔIPub	5.8779
ΔY/ΔIPPP	24.3432
$\frac{\Delta Y}{\overline{\Delta IPPP + \Delta IPub + \Delta IPriv}}$	2.6077
Rate of return	
Parcial rate of return	**0.0926**
Total rate of return	**0.0491**

Table 2.11. Partial and total rates of returns deriving from an impulse in private investment

Impulse response functions acumulated results	
ΔlogY	0.0393
Δlog Ipriv	0.0982
Δlog Ipub	0.0506
Δlog IPPP	0.2915
ε_{IPriv}	**0.3998**
ε_{IPub}	0.7755
ε_{IPPP}	0.1347
$\overline{Y}/\overline{IPriv}$	5.5245
$\overline{Y}/\overline{IPub}$	33.7169
$\overline{Y}/\overline{IPPP}$	250.0058
ΔY/ΔIPriv	2.2089
ΔY/ΔIPub	26.1464
ΔY/ΔIPPP	33.6843
$\frac{\Delta Y}{\overline{\Delta IPPP + \Delta IPub + \Delta IPriv}}$	1,9207
Rate of return	
Parcial rate of return	**0.0404**
Total rate of return	**0.0332**

Figure 2.4. Countries' percentage shares of value of projects of European PPPs, 1990-2009 aggregate



Source: Kappeler and Nemoz (2010)

Chapter 3

The Dynamic Impact of Government Spending and Public Private Investment on Output: Panel VAR Evidence from 14 OECD Countries

3.1 Introduction

The capacity of public consumption and public investment to influence the economic activity of a country is crucial in an economic environment such as the European Monetary Union (EMU), in which fiscal policy is the only instrument that governments have to offset idiosyncratic shocks. However, there is no consensus about the qualitative effects of fiscal policy. While Keynesian economists predict an increase in private consumption and investment and, consequently, a boost in the economic performance following an innovation on government spending, the neoclassical models suggest that after a positive shock to government consumption there will be a withdrawal of resources from private sector that is expected to reduce private consumption and investment.

A large body of empirical literature has been investigating the impact of public capital on the private sector and on the economy as a whole. However, as pointed out by Perotti (2007), so far the literature has not been able to provide robust stylized facts on the effects of fiscal policy shocks.

Vector autoregression (VAR) shocks to government spending seem to be associated with a rise in output. For instance, using a mixed structural VAR/event approach,

Blanchard and Perotti (2002) concluded that positive government spending shocks have a positive effect on output, on hours, consumption and real wages. Follow-up work, such as Galí, López-Salido, and Vallés (2007) extended the standard new Keynesian model to allow for the presence of rule-of-thumb consumers, showing that consumption rises as a consequence to a shock in government spending. Fatas and Mihov (2002) found strong evidence in favor of the hypothesis that large governments reduce the volatility of both private and total output. However, Mountford and Uhlig (2005) and Edelberg et al. (1999) provided evidence that the response of private consumption is close to zero and not statistically significant over the entire horizon of the impulse response. Linnemann (2005) questioned if there is really a mismatch between business cycle theories and the evidence, showing that the evidence can be explained by a standard real business cycle type model. In fact, with a non-additively separable utility function and a small intertemporal consumption elasticity, higher fiscal spending can raise consumption and lower investment, as is seen in the data. Caldara and Kamps (2008) also defend that controlling for differences in specification of the reduced-form model, all identification approaches used in the literature yield qualitatively and quantitatively very similar results as regards government spending shocks.

Against this background this chapter aims to provide evidence on the effects on a set of key macroeconomic variables to shocks to public consumption, public investment, and private investment for two distinct groups of countries that were formed according to their capacity to refinance their government debt or to bail out over-indebted banks on their own during the recent crisis of 2008-2014.

To do so, a panel VAR framework was used. This chapter relies on macroeconomic time series data alone for shock identification, thereby not imposing any restriction of the responses of the key variables to shocks to public consumption, public investment, and private investment.

The rest of the chapter is organized as follows: Section 2 describes the data and econometric methodology underlying our empirical application. Section 3 discusses the empirical results of this study. Section 4 summarizes the main findings.

3.2. Econometric methodology

As in a VAR model, in a panel VAR all variables are treated as endogenous and interdependent. However, the panel VAR approach also allows for unobserved individual heterogeneity, adding a cross-sectional dimension to the model. The dynamic interdependencies, the static interdependences, and the cross-sectional interdependencies distinguish the panel VARs typically used in macroeconomics and financial analyses from the initial work from Holtz Eakin, et. al (1988), in which interdependencies were disregarded and sectoral homogeneity was assumed. As put by Canova and Ciccarelli (2013) "a panel VAR is similar to large scale VARs where dynamic and statistic interdependencies are allowed for. It differs because cross sectional heterogeneity imposes a structure on the covariance matrix of the error terms."

As pointed out by Baltagi (2005), the use of panel data allows the control of the individual heterogeneity of each section, the use of more information and more variability, less collinearity between the variables, higher degrees of freedom and more efficiency. The use of panel data also allows the study of dynamics of adjustment to changes that arise unexpectedly, and are better at identifying and quantifying effects that are not detected in the data.

Panel VARs have been used to address many macroeconomic issues. The panel VAR technology has been applied in the fields of business cycle literature as in Canova et al. (2007) and in Canova and Ciccarelli (2012), and to construct coincident or leading indicators of economic activity in Cannova and Ciccarelli (2009). De Grave and Karas (2012) and Canova (2004) used this technique to examine the extent of dynamic heterogeneity and of convergence clubs. The transmission of idiosyncratic shocks can also be studied using panel VARs. For example, Caivano, M. (2006) analyzed how disturbances in the Euro area are transmitted to the U.S. and *vice versa*. Ciccarelli et al. (2012a) investigated heterogeneity and spillovers in macro-financial linkages across developed economies, with emphasis on the most recent recession. Beetsma and Giuliadori (2011) reviewed the theoretical consequences of government purchases shocks for both closed and open economies, showing that among other things, an increase in government purchases raises output, consumption, and investment and reduces the trade balance. Lane and Benetrix (2011) also examined the cross-country dispersion in fiscal outcomes during 2007-2009. Finally, the dynamic relationship between firms' financial conditions and investment was studied by Love and Zicchino (2006), who concluded that the impact of financial factors on investment, which indicates

the severity of financing constraints, is significantly greater in countries with less developed financial systems.

Another application of panel VARs is the construction of average effects and characterizing unit specific differences in relation to the average. In this area, Canova and Pappa (2014) studied the effect of regional expenditure and revenue shocks on price differentials for 47 US. states and 9 EU countries and concluded that on average, expansionary fiscal disturbances produce positive price differential responses, while distortionary balance budget shocks produce negative ones. Rebucci (2010) examined the role of external and policy factors for growth variability and concluded that temporary external shocks are an important determinant of medium to long-run growth variability and that high inflation countries are more vulnerable to external shocks than others. Ciccarelli et al. (2012) investigated how financial fragility affected the transmission mechanism of the single Euro area monetary policy during the crisis until the end of 2011, concluding that the monetary transmission mechanism was time-varying and influenced by the financial fragility of the sovereigns, banks, firms, and households.

3.2.1 Data

We used a panel data for 14 European countries to study the dynamic relationship between public consumption and investment, private investment, and output level. Annual data over the period 1995-2016 were used for 14 countries: Austria (AT), Belgium (BE), Denmark (DK), Finland (FI), France (FR), Germany (DE), Greece (GR), Ireland (IE), Italy (IT), Netherlands (NL), Portugal (PT), Spain (ES), Sweden (SE) and the United Kingdom (UK). Annual data were used instead of quarterly observations as there is no quarterly calendar for fiscal policy, and for that reason shocks identified with annual data may be closer to the actual shocks. See Beetsma, Giuliodori, and Klaassen (2008) and Ramey (2006). The main drawback of annual data is the exclusion of within-year responses to shocks and also the fact that fewer observations are available. Being so, to increase the precision of our estimates panel VAR data were used.

All variables are presented at constant prices and in logarithmic growth rates of the original values. GDP was transformed into real values using the GDP price deflator. The price deflator for gross fixed capital formation was used to transform both private investment and public investment from current to constant prices. The data for public consumption were already at constant prices of 2010. All data were collected from AMECO.

3.2.2 Structure of the model

As mentioned above, our main goal is to compare the response of GDP to a shock in public consumption, public investment, and private investment for the group of 14 European countries under analysis and also to check for crowding-out effects or crowding-in effects. To investigate if there are significant differences between these countries, "all countries", we split them into two groups: a first group of five Southern European countries which, during the European debt crisis, were unable to refinance their government debt or to bail out over-indebted banks on their own, and a second group of the nine remaining countries, which did not suffer from such severe economic difficulties. The first group, hereinafter the "peripheral countries", comprises Greece, Ireland, Italy, Portugal, and Spain; the second group, hereinafter "core countries" comprises Austria, Belgium, Denmark, Finland, France, Germany, Netherlands, Sweden and the United Kingdom.

Panel VARs and VAR models have the same structure as all variables are assumed to be endogenous and interdependent but in Panel VARs a cross sectional dimension is added. The representation of a panel VAR is the following:

$$y_{it} = A_{0i}(t) + A_i(l)Y_{1t-1} + u_{it} \quad (1)$$

where u_t is a $G\ X\ 1$ vector of random disturbances and A_{0i} and A_i may depend on the unit.

The representation of a panel VARX is:

$$y_{it} = A_{0i}(t) + A_i(l)Y_{1t-1} + F_i(l)W_t + u_{it} \quad (2)$$

where $u_t = [u_{1t}, u_{2t}, \dots, u_{Nt}]' \sim iid(0, \sum)$, $F_{i,j}$ are GxM matrices for each $j = 1, \dots, q$ and W_t is a Mx1 vector of predetermined or exogenous variables, common to all units i.

As pointed out by Canova and Ciccarelli (2013), Panel VARs present three characteristic features: "dynamic interdependences" that is, lags of all endogenous variables of all units enter the model for unit i; "static interdependences" since u_{it} are generally correlated across i, and "cross sectional heterogeneity", that is, the intercept, the slope and the

variance of the shocks u_{it} may be unit specific. However these three characteristic features do not have to be included in all applications.

We specified the VAR model as follows:

$$Y_{it} = A_0 + A_1 Y_{it-1} + f_i + e_t \quad (3)$$

where $i = 1, \ldots, N$ indicates countries, $t = 1, \ldots T$ indicates time, Y_{it} is a four-variable vector $\{PUBCONSUMP_{it}, PUBINV_{it}, PRIVINV_{it}, GDP_{it}\}$. PUBCONSUMP is the logarithmic growth rates of public consumption, PUBINV is the logarithmic growth rates of public investment, PRIVINV is the logarithmic growth rates of private investment, and GDP is the logarithmic growth rates of real gross domestic product. e_t is a vector of random disturbances.

To apply the VAR approach to panel data, the underlying structure has to be the same for each cross-sectional unit. This constraint is very unlikely to be verified. One way to overcome this restriction on parameters is to introduce fixed effects in the model, f_i, i.e., allowing for "individual heterogeneity" in the levels of the variables.

Using the reduced form VAR is useful as it allows for the implementation of dynamic simulations, once the unknown parameters are estimated. These simulations typically involve impulse response analysis and variance decompositions, making it possible to understand the impact of a shock in any particular variable on the other variables in the system, while holding everything else equal. However, to isolate shocks in one specific variable in the system the residuals must be decomposed in such a way that they become orthogonal. To do so the variables in the VAR were ordered from what is theoretically considered the most exogenous variable to the least exogenous one, with public consumption ordered first, followed by public investment, private investment, and output. This identification assumption follows earlier research in ordering public consumption before output, see Bénétrix and Lane (2013) and Beetsma, Giuliodori, and Klaassen (2005). A shock in public consumption may have an instantaneous effect on all of the other variables. However, public consumption does not respond contemporaneously to structural disturbances in the other variables. A shock in public investment, the second variable, does not have an instantaneous impact on public consumption, only on private investment and output. Indeed, one can recall that

governments typically announce their spending and investment plans in advance. As a result, economic agents can incorporate this information in their decisions.

3.2.3 Unit Root Tests

The Im, Pesaran, and Shin (2003) test, which is based on the Dickey-Fuller procedure, was used to investigate the presence of unit roots in panels. This test combines information from the time series dimension with information from the cross-section dimension, such that fewer time observations are required in order for the test to have power. Table 3.1 reports the results for the Im, Pesaran, and Shin test on levels with trend and without trend, for all variables, for the peripheral, core, and all countries respectively.

Table 3.1. Panel Unit Root Test – Im, Pesaran and Shin

	Peripheral countries		**Core countries**		**All countries**	
Variable	**Individual effects**	**Individual effects + individual linear trends**	**Individual effects**	**Individual effects + individual linear trends**	**Individual effects**	**Individual effects + individual linear trends**
PUBCONSUMP	-1.67634* (0.0468)	0.94613 (0.8280)	1.46951 (0.9292)	2.58483 (0.9951)	0.17643 (0.5700)	2.63790 (0.9958)
PUBINV	-0.18900 (0.4250)	0.91863 (0.8209)	1.48100 (0.9307)	-1.77453* (0.0380)	1.07449 (0.8587)	-0.87380 (0.1911)
PRIVINV	-0.44872 (0.3268)	-0.20563 (0.4185)	-2.01478* (0.0220)	-2.43583* (0.0074)	-1.88358* (0.0298)	-2.07590* (0.0190)
GDP	-1.92880* (0.0269)	-0.32383 (0.3730)	-1.75656* (0.0395)	-0.39816 (0.3453)	-2.56106* (0.0052)	-0.51277 (0.3041)

* indicates rejection of the null hypothesis of no-cointegration at 5% level of significance

3.2.4 Lag Length Decision

The standard information criteria (Akaike and the Schwartz) were employed to select the appropriate lag-length. The results can be found in Table 3.2. Taking into account the length of the data used in the panel VAR, these standard information criteria tests, and the panel VAR residual correlation LM tests (results presented in Table 3.3) a model with three lags was chosen for the “peripheral countries” model, two lags were used in the case of the “core countries”, and four lags were employed when taking the 14 countries into consideration.

Table 3.2. Lag Order Selection Criteria

	Peripheral countries		Core countries		All countries	
Lag	AIC	SC	AIC	SC	AIC	SC
0	-11.13296	-10.46391	-13.31107	-12.46117	-10.44827	-9.462424
1	-11.77683	-10.57256	-16.32958	-15.10195*	-13.86896	-12.60144
2	-12.32679	-10.58728*	-16.55004	-14.94467	-14.29229	-12.74310*
3	-12.27219	-9.997449	-16.64674*	-14.66364	-14.55119	-12.72033
4	-12.31009	-9.500115	-16.60779	-14.24696	-14.66947*	-12.55694
5	-12.43994	-9.094724	-16.43356	-13.69499	-14.57275	-12.17854
6	-12.44142	-8.560973	-16.30960	-13.19330	-14.52309	-11.84721
7	-12.51399	-8.098314	-16.20319	-12.70916	-14.47074	-11.51319
8	-13.00972*	-8.058803	-16.24182	-12.37005	-14.50874	-11.26952

* indicates lag order selected by the criterion
AIC: Akaike information criterion
SC: Schwarz information criterion

Table 3.3. VAR Residual Serial Correlation LM Tests

	Peripheral countries		Core countries		All countries	
Lags	LM-Stat	Prob	LM-Stat	Prob	LM-Stat	Prob
1	25.87358	0.0558	21.25005	0.1691	15.49920	0.4884

3.3. Dynamic Analysis

The estimated parameters of the panel VAR for the “peripheral countries”, “core countries”, and for “all countries” can be found in Tables 3.4 to 3.6 of the Appendix, respectively.

3.3.1 Impulse Response Functions

To understand the impulse response functions (IRFs), one needs an estimate of their confidence interval. Being so, a 95 percent confidence band around estimates was included.

- **Peripheral countries**

The IRFs for the “peripheral countries” are plotted in Figs.3.1 to 3.3.

Figure 3.1. Responses to shocks in public consumption – Peripheral Countries

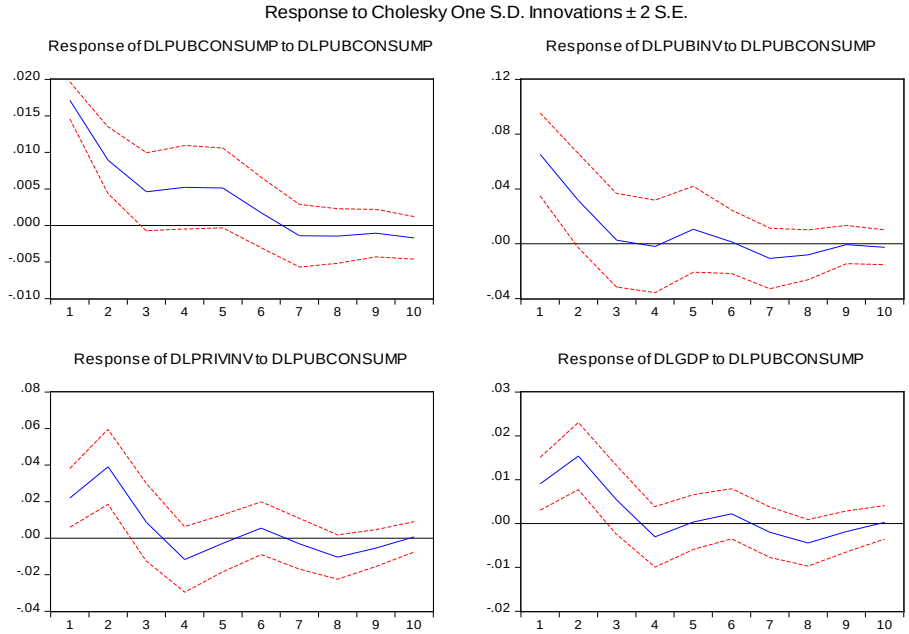
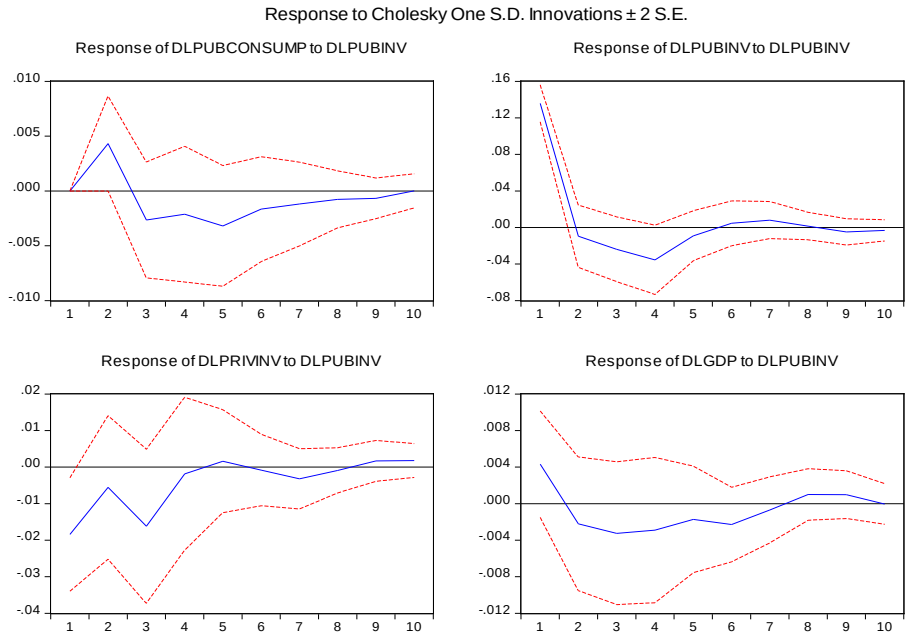


Figure 3.1 shows the impact of a Cholesky one standard error positive shock to public consumption in this group of countries. The impact in public consumption persists over a 2-3 years period. The response of public investment is positive in both the estimated coefficient for the first lag and impulse responses. This is expected as public investment responds positively to an increase in GDP and to support the expansion of private investment. In fact, the average GDP of these five economies responds positively to a shock in public consumption. The impact on private investment is also positive and the peak response of private investment is approximately after a year and a half, thereafter converging to its pre-shock level. Its peak response coincides with the one from GDP.

Figure 3.2. Responses to shocks in public investment – Peripheral Countries

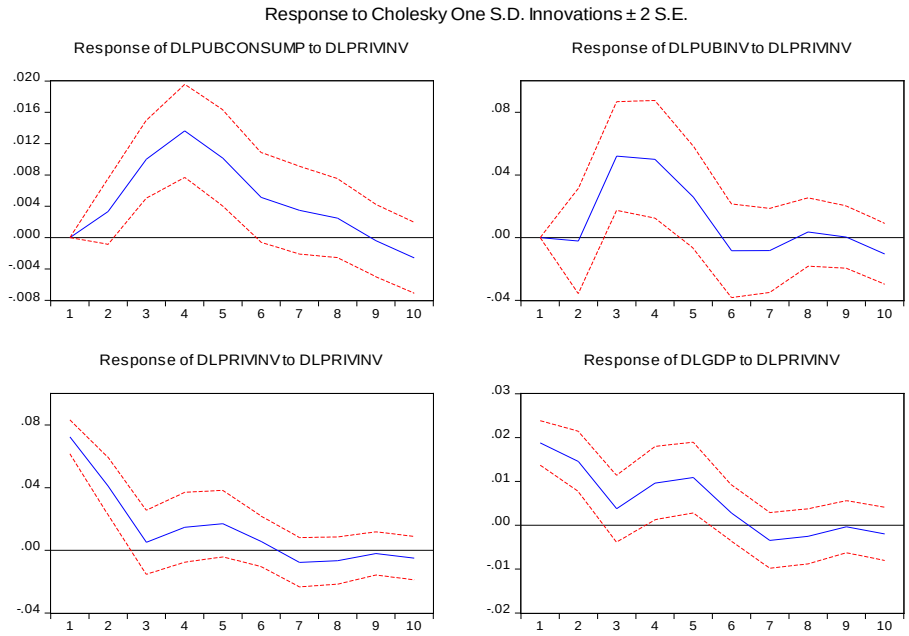


As plotted in Figure 3.2, Cholesky one standard error positive shock to public investment presents an initial crowding-out effect in "peripheral countries", as the impact on private investment is negative. In fact, macroeconomic rationale suggests that an increase in public investment can have two opposite effects on private investment, Aschauer (1989b) and Mittnik and Neumann (2000). As an increase in public investment is partly funded in the capital markets, this would lead to a reduction in the funds available to private investors and to an increase in interest rates charged by lenders, causing a decrease in the rate of return of private investment, and thus crowding-out of this type of investment. On the contrary, an increase in public investment results in an increase in domestic production, which allows private investors to become more optimistic about the future, and creating more favorable conditions for investment by the private sector. The response of public consumption seems to be positive in the first two years after a positive shock to public investment and, concerning GDP, it does not seem to react in a statistically significant manner.

To investigate the role of private investment in the "peripheral countries" we show in Figure 3.3 the IRFs for a one standard error positive shock to this variable. We find that an increase in private investment does not have an immediate impact on public consumption. However, this variable will respond positively reaching the maximum impact approximately four years after the shock. One finds a similar behavior of public investment, that is, there is evidence of a crowding-in effect not immediately after the shock but approximately between the third and fifth year thereafter. GDP responds

positively to an increase of private investment, with this response reaching its greatest magnitude immediately after the shock. This positive answer persists over a period of five years, although in the third year the response does not seem to be statistically significant.

Figure 3.3. Responses to shocks in private investment – Peripheral Countries



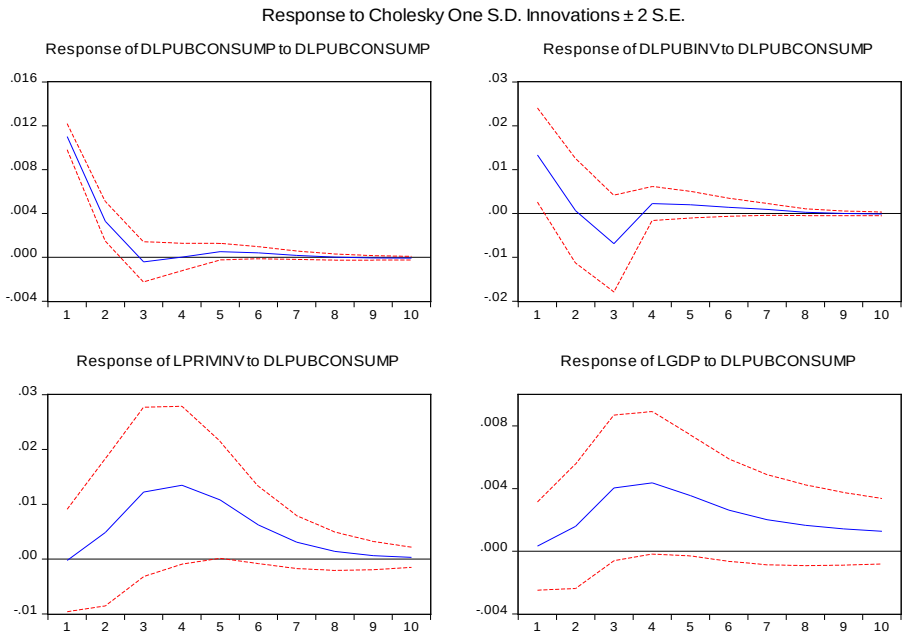
In conclusion, in the case of the "peripheral countries", the optimal measures to boost the economy seem to be either a positive shock to public consumption or a positive shock to private investment, as in both cases GDP will tend to increase and one will find crowding-in effects. The use of public consumption as a measure to help to improve the performance of these economies does not seem to be efficient, as GDP does not respond to it.

- **Core countries**

The IRFs for the "core countries" can be found in Figures 3.4 to 3.6. Figure 3.4 shows that in this group of countries a Cholesky one standard error positive shock to public consumption persists over time, as it takes roughly five years to return to its previous value. Public investment responds positively in the first year after an increase in public consumption. This same result can be found in the estimated coefficient for the first lag. This may be due to a complementary effect between current and capital expenses. Such a policy change does not have a statistically significant impact on private investment,

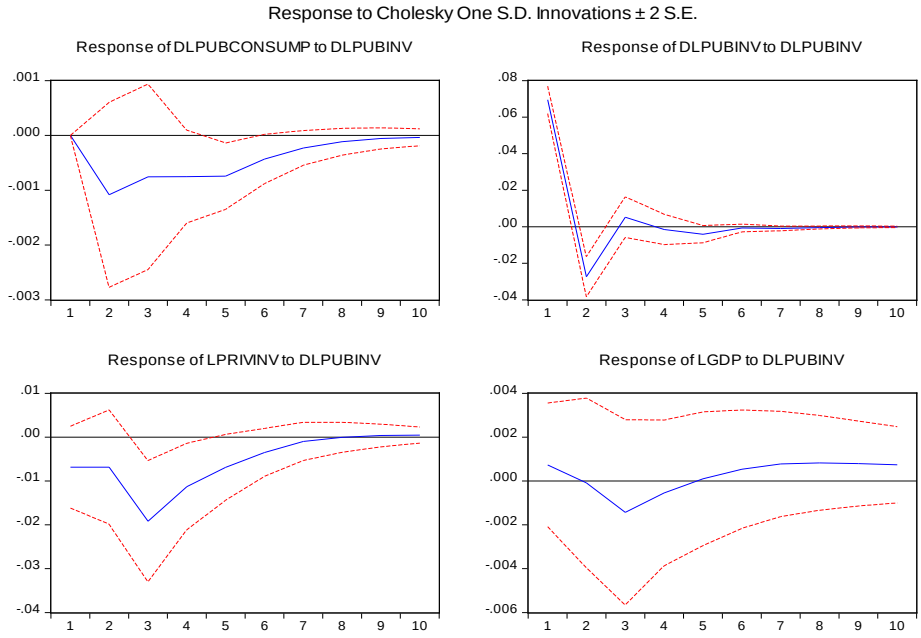
except for a slight positive effect between the fourth and fifth year following the shock. The average output of these countries does not respond to changes in public consumption.

Figure 3.4. Responses to shocks in public consumption – Core Countries



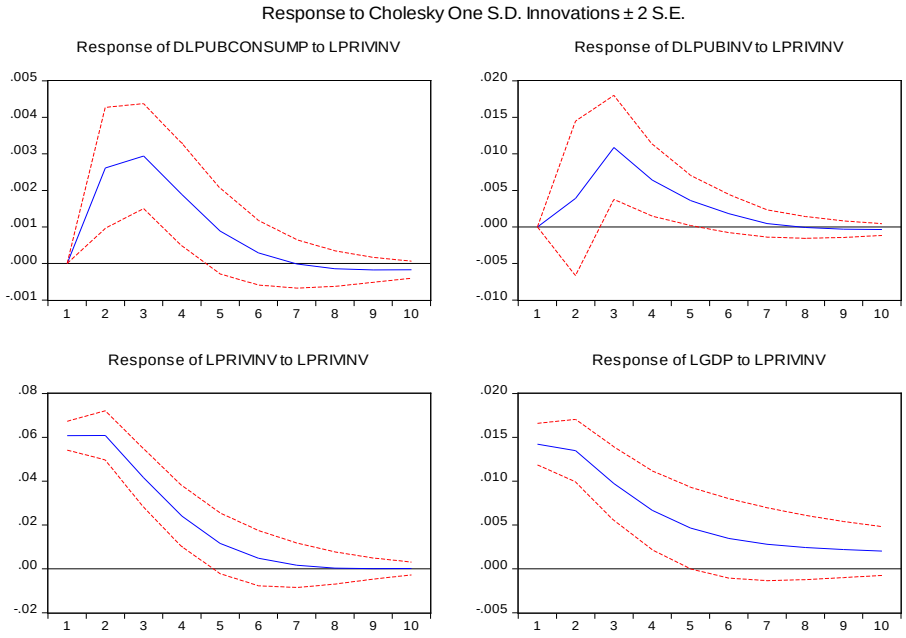
A Cholesky one standard error positive shock to public investment does not seem to be able to boost the output of these economies – much to the contrary, a statistically significant crowding-out effect occurs between the second and fourth year after the shock. The impact of this change on public consumption is limited to a decrease in the fifth year following the innovation. See Figure 3.5.

Figure 3.5. Responses to shocks in public investment – Core Countries



The role of private investment in the "core countries" is seen in Figure 3.6, in which the IRFs from a one standard error positive shock to this variable are plotted. The impact of this innovation seems to be positive and persistent over time, as public consumption, GDP, and private investment itself take four years to converge to their initial levels. In relation to the response of public investment we find a statistically significant crowding-in effect approximately between the second and fourth year after the shock.

Figure 3.6. Responses to shocks in private investment – Core Countries

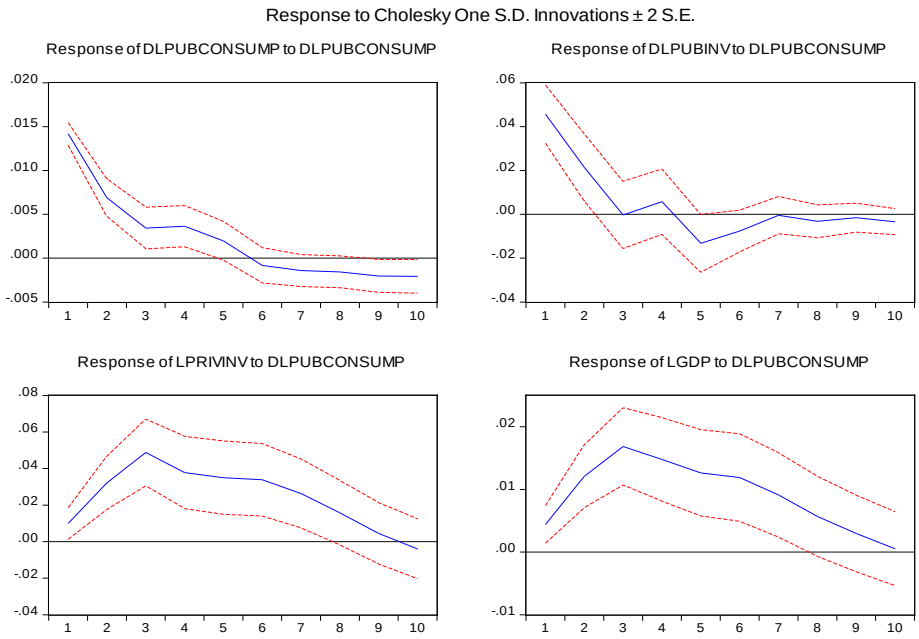


Concluding, in the case of the “core countries” the most adequate measure to help to improve economic growth seems to be an increase in private investment.

- **All countries**

The IRFs for the whole sample of the 14 countries are plotted in Figures 3.7 to 3.9. In the case of these countries a Cholesky one standard error positive shock to public consumption will impact positively in private investment and in GDP for about eight years after the shock, reaching, in both cases, its peak response between the second and third year. The effect on public investment is also positive, but in this case statistically significant in only the first two years after the change. These same results can be found in the estimated coefficient for the first lag.

Figure 3.7. Responses to shocks in public consumption – All Countries



When we investigate the impact of a Cholesky one standard error positive shock to public investment we conclude that after the initial increase, mainly in the first year, public investment tends to decrease in the period between the second and the fifth year following the shock. This change does not impact public consumption or GDP in a statistically significant way. In terms of the response of private investment, we find a crowding-out effect until roughly the fourth year after this shock. See Figure 3.8.

Figure 3.8. Responses to shocks in public investment – All Countries

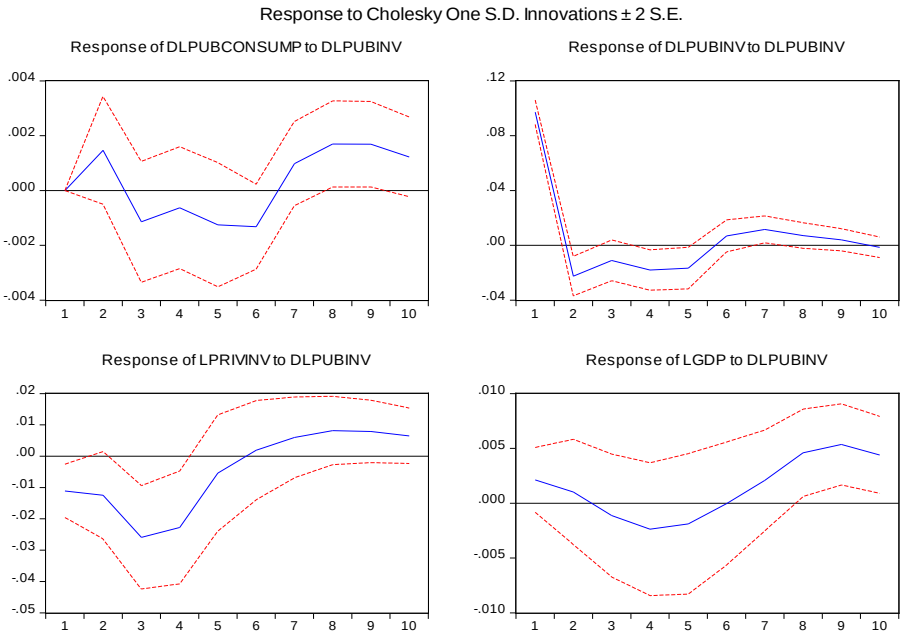
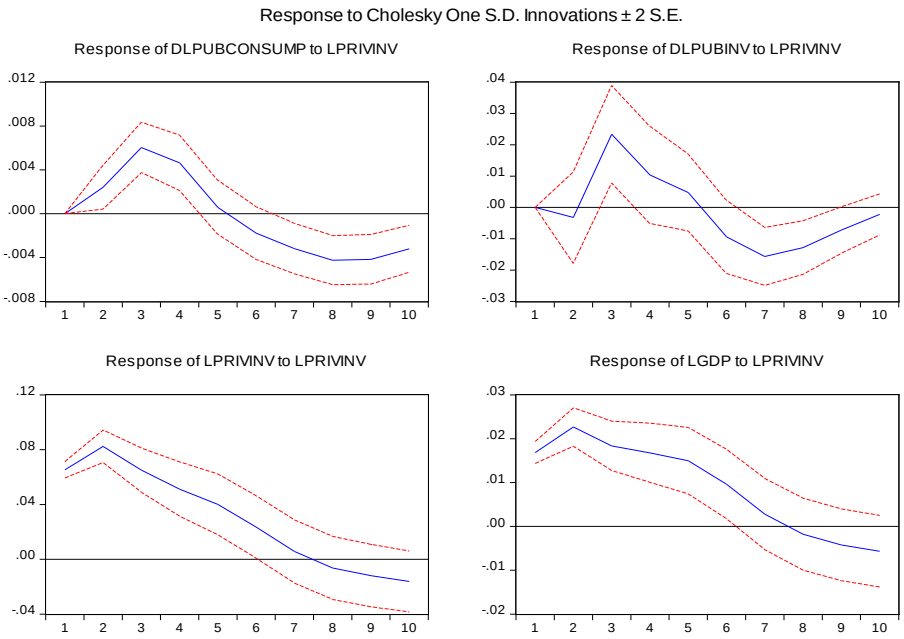


Figure 3.9. Responses to shocks in private investment – All Countries



As can be seen in Figure 3.9, a Cholesky one standard error positive shock to private investment leads to an initial increase in public consumption that persists over approximately 4 years. Relative to public investment we find a crowding-in effect between the second and third year after the shock, and later on, between the sixth and ninth year a crowding-out effect. The average GDP of the 14 countries shows behavior

similar to that of private investment, which is a persistent increase until the sixth year, naturally with a lower magnitude.

In summary, the most efficient way to influence the economic performance of this group of countries, “all countries”, is to cause an increase in public consumption or in private investment.

Taking into account the above analysis, it is clear that countries do not react in the same way to a rise in public consumption, public investment, or private investment. In fact, public consumption plays an active role only in those economies that suffered severe economic consequences in the recent crisis. Private investment allows a boost in the output of both the “peripheral countries” and the “core countries”.

3.3.2 Variance Decomposition

To study the relative importance of each random innovation in affecting the variables in the VAR, the Variance Decomposition (VD) was estimated. Tables 3.7 to 3.9 of the Appendix report the VD of public consumption, public investment, private investment, and GDP to the groups of the “peripheral countries”, “core countries”, and also of the “all countries”, respectively. The results are in line with the IRFs analyzed previously. The first period decomposition for the first variable in the VAR ordering is due completely to its own innovation.

In the case of the “peripheral economies” a shock to private investment can explain about 2% of the variation of the fluctuation in public consumption in the second year after the innovation and about 38% at a five years horizon. That is, private investment has the power to explain about the same percentage of the variation of the fluctuation in public consumption as it has public consumption in itself. Regarding public investment, a shock in public consumption can cause about 16% variation of the fluctuation in public investment and private investment about 18%. The forecast variation of private investment after a shock in this same variable is almost 69%, an innovation in public consumption being responsible for about 21% of the fluctuation in private investment.

In “core countries” especially it is showed that at the five years horizon an impulse in private investment can explain about 13% variation of the fluctuation in public consumption, and only about 2% can be explained by an innovation on public investment. Regarding public investment, at a five year horizon almost 91% of the forecast variation is due to an innovation in public investment itself. Public consumption

and private investment contribute to about 4% and 3% of the forecast variation in public investment, respectively. Again, almost 89% of variation of the fluctuation in private investment can be justified by a shock in this same variable, and only about 6% and 4% can be explained by impulses in public investment and public consumption, respectively.

Finally, if taking into account the 14 countries ("all countries") and a time horizon of ten years, an innovation on private investment is responsible for almost 27% of the forecast variation of public consumption. Only about 3% variation of the fluctuation in public consumption is due to public investment. After a ten year period almost 63% of forecast variation in public investment is caused by a shock in public investment itself. An increase in public consumption can cause approximately 27% variation of the fluctuation in private investment, an innovation on public investment is responsible for only about 6% variation of the fluctuation in private investment, and a shock to private investment itself can explain almost 67% of variation of the forecast variation of private investment.

3.3.3 Robustness tests

To test the robustness of the model results to the number of lags employed in the PVAR, we re-estimated the PVAR models using four and five lags in the case of the "peripheral countries", three and four lags concerning the "core countries", and five and six lags when referring to the model with "all countries" included. These re-estimated models deliver similar, if not identical, results in terms of the impulse response functions.

Although we order the variables in the model according to what is commonly adopted in the literature, we assess the sensitivity of the results to a change in this order, namely, ordering public investment as the most exogenous variable followed by public consumption, private investment, and GDP. In general, the results are very similar. The main differences rely on the fact that in some cases the impact of the shocks becomes statistically insignificant.[1]

3.4. Conclusions

Based on a panel VAR technology and in particular on the Impulse Response Functions and Variance Decomposition, we analyzed the dynamic impacts of public consumption,

[1] Results for different number of lags and for changes in the order of the variables are available upon request.

public investment, and private investment on GDP in the period 1995-2016 in two groups of countries: “peripheral countries” and “core countries”, which were classified according to the economic difficulties they faced in the recent crisis of 2008-2014.

Our findings suggest that in the case of the “peripheral countries” the optimal measure to boost the economy is to raise public consumption or private investment, as in both cases GDP will tend to increase and one will find crowding-in effects. On the contrary, an innovation to public investment does not seem to be efficient, as GDP does not respond to it and one finds a crowding-out effect on private investment. Concerning the “core countries”, the most adequate measure to improve economic growth seems to be an increase in private investment, as GDP does not respond at all to a shock to public consumption or to public investment. Finally, if one takes into account all 14 countries in this analysis, the most efficient way to influence the economic performance of this group of countries, “all countries”, is an increase in public consumption or in private investment, as GDP does not respond in a statistically significant way to a shock to public investment.

It is clear from our analysis that countries do not react in the same way to shocks to public consumption, public investment, and private investment. In fact, public consumption plays an active role only in those economies that suffered severe economic consequences in the recent crisis. Private investment allows a boost in the output of both the “peripheral countries” and the “core countries”. There are several reasons to believe that during an economic crisis fiscal multipliers are larger, see Blanchard and Leigh (2013), in particular in countries that are below their productive capacity, as we assume is the case of the “peripheral countries”. As pointed out by Christiano, Eichenbaum and Rebelo (2011) central banks have less room to cut rates to offset negative impacts of fiscal consolidation on the economic activity, when nominal interest rates are near zero and a poorly functioning financial system creates significant constraints on credit grant which impacts both the current level of consumption and investment. On the other hand, Nailwaik (2011) and Sheets (2011) also pointed out that a country that presents a large output gap is more vulnerable to stall and slip into recession, as there are good reasons to believe that negative shocks in the economy, when growth is already very low, can lead to a number of vicious cycles. Taking these arguments into account, it is not surprising that an increase in public consumption only impacts on the “peripheral countries” GDP as those were the countries that suffered from severe economic difficulties during the crisis in analyzed.

3.5 Appendix

Table 3.4. Panel VAR Estimates - Peripheral countries

	DLPUBCONSUMP	DLPUBINV	DLPRIVINV	DLGDP
DLPUBCONSUMP(-1)	0.342721	2.238042	1.445907	0.614468
	(0.12866)	(1.13230)	(0.58567)	(0.21971)
DLPUBCONSUMP(-2)	-0.193602	-1.152165	-0.559006	-0.241032
	(0.12241)	(1.07731)	(0.55723)	(0.20904)
DLPUBCONSUMP(-3)	-0.077571	-0.618157	-0.603828	-0.230923
	(0.09250)	(0.81405)	(0.42106)	(0.15796)
DLPUBINV(-1)	0.010027	-0.155003	-0.000503	-0.005433
	(0.01546)	(0.13603)	(0.07036)	(0.02640)
DLPUBINV(-2)	-0.021925	-0.105321	-0.181791	-0.017061
	(0.01531)	(0.13475)	(0.06970)	(0.02615)
DLPUBINV(-3)	-0.010054	-0.262639	0.120857	0.042650
	(0.01556)	(0.13696)	(0.07084)	(0.02658)
DLPRIVINV(-1)	-0.062405	-0.339283	0.425921	0.137219
	(0.03578)	(0.31486)	(0.16286)	(0.06110)
DLPRIVINV(-2)	0.048716	0.836609	-0.330457	0.017390
	(0.03597)	(0.31659)	(0.16375)	(0.06143)
DLPRIVINV(-3)	-0.016031	-0.085715	0.280541	0.179301
	(0.03762)	(0.33103)	(0.17122)	(0.06423)
DLGDP(-1)	0.418407	1.195704	0.546054	0.245421
	(0.09596)	(0.84450)	(0.43681)	(0.16387)
DLGDP(-2)	0.098029	-1.056546	-0.063706	-0.466385
	(0.13818)	(1.21605)	(0.62899)	(0.23596)
DLGDP(-3)	0.359521	1.261041	-0.444923	-0.215152
	(0.14319)	(1.26012)	(0.65179)	(0.24452)
C	-0.010919	-0.052931	0.020734	0.045094
	(0.00673)	(0.05923)	(0.03064)	(0.01149)
D2	0.009692	0.055469	-0.049857	-0.030469
	(0.00660)	(0.05810)	(0.03005)	(0.01127)
D3	0.019906	-0.008226	-0.018996	-0.027274
	(0.00684)	(0.06022)	(0.03115)	(0.01169)
D4	0.012645	0.034125	-0.025201	-0.040752
	(0.00736)	(0.06479)	(0.03351)	(0.01257)
D5	0.009153	-0.021275	-0.036411	-0.031726
	(0.00656)	(0.05771)	(0.02985)	(0.01120)

Number of obs. 90 after adjustments

Table 3.5 Panel VAR Estimates - Core countries

	DLPUBCONSUMP	DLPUBINV	LPRIVINV	LGDP
DLPUBCONSUMP(-1)	0.314191	0.531697	0.468288	0.129655
	(0.08047)	(0.51699)	(0.44663)	(0.13488)
DLPUBCONSUMP(-2)	-0.142734	-0.729456	0.764631	0.223892
	(0.07575)	(0.48671)	(0.42046)	(0.12697)
DLPUBINV(-1)	-0.014169	-0.418760	-0.019457	-0.013016
	(0.01213)	(0.07792)	(0.06732)	(0.02033)
DLPUBINV(-2)	-0.005121	-0.045699	-0.209856	-0.027517
	(0.01144)	(0.07347)	(0.06347)	(0.01917)
LPRIVINV(-1)	0.023421	-0.154537	0.864744	-0.012425
	(0.02121)	(0.13627)	(0.11772)	(0.03555)
LPRIVINV(-2)	0.026035	0.389858	-0.240981	-0.043639
	(0.02125)	(0.13654)	(0.11796)	(0.03562)
LGDP(-1)	0.083944	0.935932	0.587246	1.000781
	(0.07478)	(0.48047)	(0.41508)	(0.12535)
LGDP(-2)	-0.138280	-1.108540	-0.389579	-0.045059
	(0.07029)	(0.45162)	(0.39015)	(0.11782)
C	0.118257	0.034992	0.430067	0.505057
	(0.06061)	(0.38944)	(0.33644)	(0.10160)
D2	0.119432	0.430943	-0.536678	0.037839
	(0.02826)	(0.18155)	(0.15684)	(0.04736)
D3	0.015822	-0.111080	0.309468	0.191651
	(0.02050)	(0.13174)	(0.11381)	(0.03437)
D4	0.013825	-0.101692	0.268378	0.165126
	(0.01782)	(0.11451)	(0.09892)	(0.02987)
D5	0.016381	-0.006986	0.028705	0.045265
	(0.00699)	(0.04490)	(0.03879)	(0.01171)
D6	-0.003170	-0.012661	-0.032566	-0.018197
	(0.00410)	(0.02637)	(0.02278)	(0.00688)
D7	-0.003296	0.042645	-0.147038	-0.069037
	(0.00779)	(0.05002)	(0.04321)	(0.01305)
D8	0.124061	0.396953	-0.456936	0.105026
	(0.03260)	(0.20942)	(0.18092)	(0.05463)
D9	0.013384	-0.064696	0.246338	0.150952
	(0.01567)	(0.10066)	(0.08696)	(0.02626)

Number of obs. 171 after adjustments

Table 3.6. Panel VAR Estimates - All countries

	DLPUBCONSUMP	DLPUBINV	LPRIVINV	LGDP
DLPUBCONSUMP(-1)	0.408144	2.354341	1.357393	0.487779
	(0.07691)	(0.58242)	(0.36339)	(0.12631)
DLPUBCONSUMP(-2)	-0.080683	-0.424237	0.940556	0.148179
	(0.07971)	(0.60362)	(0.37662)	(0.13090)
DLPUBCONSUMP(-3)	0.026893	0.804096	-0.778602	-0.154785
	(0.07274)	(0.55084)	(0.34369)	(0.11946)
DLPUBCONSUMP(-4)	-0.074205	-1.000306	0.449188	0.096080
	(0.06509)	(0.49295)	(0.30757)	(0.10690)
DLPUBINV(-1)	0.005293	-0.294511	-0.020669	-0.008150
	(0.01041)	(0.07881)	(0.04918)	(0.01709)
DLPUBINV(-2)	-0.008177	-0.121435	-0.170207	-0.015624
	(0.01028)	(0.07783)	(0.04856)	(0.01688)
DLPUBINV(-3)	0.002964	-0.254689	0.024536	0.010576
	(0.01028)	(0.07783)	(0.04856)	(0.01688)
DLPUBINV(-4)	0.003149	-0.212536	0.104936	-0.004425
	(0.00986)	(0.07464)	(0.04657)	(0.01619)
LPRIVINV(-1)	-0.033412	-0.335397	1.080399	0.053879
	(0.02190)	(0.16584)	(0.10347)	(0.03596)
LPRIVINV(-2)	0.089639	0.884198	-0.330849	-0.033140
	(0.03052)	(0.23114)	(0.14422)	(0.05013)
LPRIVINV(-3)	-0.034028	-0.618975	0.248481	0.072977
	(0.03123)	(0.23648)	(0.14755)	(0.05128)
LPRIVINV(-4)	-0.019977	0.136242	-0.306034	-0.142359
	(0.02244)	(0.16992)	(0.10602)	(0.03685)
LGDP(-1)	0.272916	1.108419	0.705025	1.135691
	(0.06264)	(0.47435)	(0.29597)	(0.10287)
LGDP(-2)	-0.249734	-2.282295	-1.289346	-0.644477
	(0.09647)	(0.73058)	(0.45584)	(0.15844)
LGDP(-3)	-0.007940	1.445981	-0.136963	0.108896
	(0.10492)	(0.79454)	(0.49574)	(0.17231)
LGDP(-4)	-0.033738	-0.485097	0.881252	0.336484
	(0.07576)	(0.57372)	(0.35796)	(0.12442)
C	0.101154	0.961171	0.366168	0.588405
	(0.07987)	(0.60487)	(0.37740)	(0.13118)
D2	0.034506	0.420029	-0.444641	0.071585
	(0.03947)	(0.29891)	(0.18650)	(0.06482)
D3	0.035935	0.291724	0.253842	0.216185
	(0.02543)	(0.19262)	(0.12018)	(0.04177)
D4	-0.013137	-0.149662	-0.127322	-0.063240
	(0.01045)	(0.07916)	(0.04939)	(0.01717)
D5	-0.006838	-0.064730	-0.206204	-0.073183
	(0.00838)	(0.06349)	(0.03962)	(0.01377)
D6	0.026925	0.076367	0.140102	0.117340
	(0.01438)	(0.10891)	(0.06795)	(0.02362)

Table 3.6. Panel VAR Estimates - All countries (cont.)

	DLPUBCONSUMP	DLPUBINV	LPRIVINV	LGDP
D7	0.030521	0.238106	0.218867	0.184105
	(0.02218)	(0.16798)	(0.10481)	(0.03643)
D8	0.025399	0.208810	0.169785	0.154078
	(0.01966)	(0.14890)	(0.09290)	(0.03229)
D9	0.016656	0.075428	0.015325	0.052777
	(0.00925)	(0.07002)	(0.04369)	(0.01518)
D10	-0.003169	-0.037760	-0.018753	-0.017776
	(0.00549)	(0.04158)	(0.02594)	(0.00902)
D11	-0.010610	-0.179553	-0.170797	-0.088592
	(0.00991)	(0.07506)	(0.04684)	(0.01628)
D12	-0.012863	-0.091326	-0.115732	-0.072765
	(0.00937)	(0.07094)	(0.04426)	(0.01538)
D13	0.038163	0.489019	-0.360467	0.150536
	(0.04596)	(0.34809)	(0.21718)	(0.07549)
D14	0.029183	0.250602	0.194558	0.171157
	(0.01936)	(0.14663)	(0.09149)	(0.03180)

Number of obs. 238 after adjustments

Table 3.7. Variance Decomposition - Peripheral countries

Variance Decomposition of DLPUBCONSUMP:

Period	S.E.	DLPUBCONSUMP	DLPUBINV	DLPRIVINV	DLGDP
1	0.02	100	0	0	0
2	0.02	78.85	3.94	2.35	14.86
3	0.03	61.30	3.99	17.30	17.41
4	0.03	46.73	3.35	32.92	16.99
5	0.03	42.84	3.87	38.27	15.02
10	0.03	40.85	4.06	40.18	14.91
20	0.03	40.40	4.08	40.61	14.90
30	0.03	40.40	4.08	40.62	14.90

Variance Decomposition of DLPUBINV:

Period	S.E.	DLPUBCONSUMP	DLPUBINV	DLPRIVINV	DLGDP
1	0.15	18.71	81.29	0	0
2	0.16	21.52	76.11	0.02	2.36
3	0.17	18.98	69.10	9.79	2.13
4	0.18	16.42	63.67	16.27	3.64
5	0.18	16.24	61.93	17.79	4.04
10	0.19	16.20	60.01	17.89	5.9
20	0.19	16.24	59.59	18.16	6.01
30	0.19	16.24	59.59	18.16	6.02

Variance Decomposition of DLPRIVINV:

Period	S.E.	DLPUBCONSUMP	DLPUBINV	DLPRIVINV	DLGDP
1	0.08	7.98	5.60	86.41	0
2	0.10	21.30	3.93	73.50	1.27
3	0.10	20.59	6.25	68.72	4.44
4	0.10	21.12	6.06	68.24	4.59
5	0.10	20.56	5.90	68.88	4.67
10	0.11	21.35	5.84	67.73	5.09
20	0.11	21.25	5.81	67.74	5.20
30	0.11	21.25	5.81	67.74	5.20

Variance Decomposition of DLGDP:

Period	S.E.	DLPUBCONSUMP	DLPUBINV	DLPRIVINV	DLGDP
1	0.03	9.62	2.18	41.21	46.99
2	0.04	23.99	1.77	42.30	31.95
3	0.04	25.10	2.45	41.61	30.84
4	0.04	23.76	2.82	44.49	28.93
5	0.04	21.94	2.79	48.33	26.94
10	0.04	22.43	3.06	47.12	27.39
20	0.04	22.36	3.09	47.45	27.10
30	0.04	22.36	3.09	47.46	27.09

Cholesky Ordering: DLPUBCONSUMP DLPUBINV DLPRIVINV DLGDP

Table 3.8. Variance Decomposition – Core countries

Variance Decomposition of DLPUBCONSUMP:

Period	S.E.	DLPUBCONSUMP	DLPUBINV	LPRIVINV	LGDP
1	0.01	100	0	0	0
2	0.01	93.63	0.83	4.85	0.69
3	0.01	87.85	1.16	10.28	0.71
4	0.01	85.36	1.49	12.28	0.86
5	0.01	84.57	1.83	12.65	0.95
10	0.01	83.99	1.97	12.64	1.39
20	0.01	83.67	1.97	12.65	1.71
30	0.01	83.63	1.97	12.65	1.76

Variance Decomposition of DLPUBINV:

Period	S.E.	DLPUBCONSUMP	DLPUBINV	LPRIVINV	LGDP
1	0.07	3.55	96.45	0	0
2	0.08	3.03	94.66	0.26	2.05
3	0.08	3.68	91.34	2.18	2.81
4	0.08	3.73	90.66	2.82	2.79
5	0.08	3.77	90.43	3.02	2.77
10	0.08	3.82	90.30	3.07	2.81
20	0.08	3.82	90.27	3.08	2.84
30	0.08	3.82	90.26	3.08	2.84

Variance Decomposition of LPRIVINV:

Period	S.E.	DLPUBCONSUMP	DLPUBINV	LPRIVINV	LGDP
1	0.06	0.00	1.26	98.74	0
2	0.09	0.31	1.24	97.82	0.63
3	0.10	1.75	4.67	92.36	1.22
4	0.10	3.29	5.45	89.80	1.46
5	0.11	4.23	5.71	88.33	1.73
10	0.11	4.63	5.76	87.49	2.12
20	0.11	4.63	5.76	87.36	2.25
30	0.11	4.63	5.76	87.34	2.28

Variance Decomposition of LGDP:

Period	S.E.	DLPUBCONSUMP	DLPUBINV	LPRIVINV	LGDP
1	0.02	0.03	0.16	59.30	40.51
2	0.03	0.40	0.08	57.85	41.68
3	0.03	2.11	0.29	53.12	44.49
4	0.03	3.56	0.27	48.95	47.22
5	0.03	4.26	0.24	45.80	49.69
10	0.04	4.58	0.38	39.03	56.01
20	0.04	4.56	0.47	36.38	58.59
30	0.04	4.56	0.49	36.00	58.96

Cholesky Ordering: DLPUBCONSUMP DLPUBINV LPRIVINV LGDP

Table 3.9. Variance Decomposition – All countries

Variance Decomposition of DLPUBCONSUMP:

Period	S.E.	DLPUBCONSUMP	DLPUBINV	LPRIVINV	LGDP
1	0.01	100	0	0	0
2	0.02	90.72	0.78	2.14	6.36
3	0.02	79.09	1.05	12.88	6.98
4	0.02	75.11	1.06	17.53	6.30
5	0.02	74.66	1.46	17.27	6.61
10	0.02	63.24	3.34	26.73	6.69
20	0.02	62.64	3.47	27.29	6.60
30	0.02	62.55	3.47	27.38	6.60

Variance Decomposition of DLPUBINV:

Period	S.E.	DLPUBCONSUMP	DLPUBINV	LPRIVINV	LGDP
1	0.11	18.12	81.88	0	0
2	0.11	19.93	77.75	0.08	2.25
3	0.12	18.65	73.65	4.08	3.63
4	0.12	18.18	73.15	4.68	3.99
5	0.12	18.77	72.63	4.67	3.93
10	0.13	18.05	69.41	7.89	4.65
20	0.13	18.26	69.00	7.99	4.74
30	0.13	18.27	68.97	8.01	4.75

Variance Decomposition of LPRIVINV:

Period	S.E.	DLPUBCONSUMP	DLPUBINV	LPRIVINV	LGDP
1	0.07	2.21	2.74	95.05	0
2	0.11	9.01	2.22	87.86	0.92
3	0.14	17.59	4.76	76.61	1.03
4	0.16	20.13	5.98	72.96	0.93
5	0.17	22.48	5.46	71.16	0.89
10	0.18	26.80	5.53	66.46	1.21
20	0.18	27.51	5.40	65.91	1.18
30	0.18	27.63	5.38	65.81	1.19

Variance Decomposition of LGDP:

Period	S.E.	DLPUBCONSUMP	DLPUBINV	LPRIVINV	LGDP
1	0.02	3.59	0.83	52.43	43.16
2	0.04	11.00	0.37	53.03	35.60
3	0.05	19.74	0.30	49.78	30.18
4	0.05	23.66	0.44	50.15	25.75
5	0.06	25.44	0.49	50.43	23.63
10	0.06	27.19	2.22	44.61	25.98
20	0.07	26.15	2.76	44.06	27.03
30	0.07	26.15	2.77	43.78	27.29

Cholesky Ordering: DLPUBCONSUMP DLPUBINV LPRIVINV LGDP

Chapter 4

The Impact of Public Investment on Peripheral Economies: A Global VAR Analysis

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4.1. Introduction

The euro area has been facing a slow, weak, and uneven recovery over the last decade. The output gap continues large and inflation is still below the ECB's goal. After the 2007-2008 crisis some euro area countries accumulated large and persistent current account deficits, and at the same time other member states presented high and persistent surpluses. For instance, at that time, the collective deficit of Greece, Ireland, Italy, Portugal, and Spain corresponded to almost 7% of their GDP, while Germany and the Netherlands recorded an almost 6% surplus of their GDP. In fact, Germany has become one of the major surplus countries in the world, with a current account surplus of 7% of its GDP in 2012. Adding to this, real interest rates are expected to remain below their pre-crisis levels for a considerable period of time, implying low government borrowing costs.

This situation has caused heated debates about the role of current account surplus countries in the European economy recovery. In fact, in advanced economies an increase in public investment is one of the few remaining policies available to push economic growth, and in developing economies an increase in infrastructure investment will allow the much needed expansion of these countries' productive capacity. However, the magnitude of public investment multipliers and how public-debt-to-GDP ratios evolve in the presence of higher public investment is not consensual.

From a theoretical point of view, there is evidence that an increase in public investment can have two opposite effects on private investment: see e.g. Aschauer (1989b) and Mittnik and Neumann (2000). On the one hand, an increase in public investment needs to be financed which may result, at least partially, in a reduction of funds available to private investors and to an increase in interest rates charged, causing a decrease in private investment, thus leading to a crowding-out effect. Conversely, in a crowding in scenario, an increase in public investment can create more favorable conditions for private sector investment, especially through the development of facilities that can increase private capital productivity.

To tackle these questions Dreger and Reimers (2014) explored the long-run relationship between public and private investment in the euro area, in terms of both capital stocks and gross investment flows using a panel vector autoregressive (VAR) model that accounted for international spillovers. The authors concluded that private investment reacts to shocks in public investment is rather exogenous and that the lack of public investment may have restricted private investment and GDP growth in the euro area. The International Monetary Fund (2014), using a structural VAR (SVAR) approach concludes that the macroeconomic impact of increasing public investment raises output in both the short and long term. On the other hand, Elekdag and Muir (2014) based on a dynamic stochastic general equilibrium (DSGE) model argued that higher German public investment would stimulate domestic demand in the short run, reduce the current account surplus, increase GDP in the longer-run and be associated with beneficial spillovers across the rest of the euro area. The authors highlighted that Germany should take advantage of the current low-interest rate environment. More recently, Blanchard, Erceg, and Lindé (2015), using a two country New Keynesian model and a large-scale DSGE model, tested the effects of a fiscal expansion by core euro area countries and how the periphery would be affected by this expansion. They concluded that periphery GDP expands as domestic demand is crowded in by lower real interest rates, net exports increase, and domestic demand expansion.

The present chapter contributes to this literature using a global vector autoregressive (GVAR) approach that, to the best of our knowledge, has not yet been used to test for the cross-country spillover effects of an increase in public and private investment in the euro area. We examine and quantify the impact of innovations to both public and private investment in a central European economy (Germany) and in a peripheral one (Portugal) into the majority of the European countries, USA and Japan.

As a first exercise, we examine the effects of an exogenous shock on Germany's and Portugal's public investment, by employing generalized impulse response functions (GIRFs), and then the impact of an exogenous shock on Germany's and Portugal's private investment.

The rest of the chapter is structured as follows. Section 2 briefly reviews the general literature about GVAR developments and its main applications, except for the question of public and private investment spillovers across countries that is presented in the introduction. Section 3 describes the macro-econometric framework underlying our empirical application. Section 4 describes the data, the GVAR model employed herein, and the estimation issues. Section 5 discusses the empirical results. Section 6 presents the concluding remarks.

4.2. The GVAR approach: a literature review

The GVAR modeling approach was introduced by Pesaran, Schuermann, and Weiner (2004). This model combines individual country-specific models in which domestic variables are related to country-specific foreign variables that match the relative importance of the rest of the world for the country under consideration, providing an effective way to deal with the curse of dimensionality. That is, it allows exploring international linkages of variables by linking country-specific $VARX^*(p_i, q_i)$ $i = 1,2,\dots,N$ models, where X^* is a vector of foreign variables that enters the country specific VAR models, and p and q are the domestic and foreign variables' number of lags, respectively. Pesaran and Smith (2006) show that $VARX^*$ models can be derived as solutions of DSGE models, demonstrating also that short and long-run restrictions, if acceptable, can be imposed on them. On its turn, Dees, Holly, Pesaran, and Smith (2007) imposed restrictions on the long-run relationships of several variables by identifying the cointegrating vectors of the country-specific vector error-correction models (VECM). Dees, di Mauro, Pesaran, and Smith (2007) derive the GVAR methodology as an approximation to a global factor model. Chudik and Pesaran (2011,

2013) extended the GVAR approach, allowing for joint asymptotics and weak cross-sectional dependence in errors in the stationary variables case.

The GVAR framework has been applied to various fields. Dees, di Mauro, Pesaran, and Smith (2006) analyze the role of credit and explored the international linkages of the euro area by presenting a theoretical framework in which the GVAR is derived as an approximation to a global unobserved common factor model. Eickmeier and Ng (2011) focused on the transmission of credit supply shocks in the US, the euro area, and Japan to other economies and found that negative US credit supply shocks have stronger negative effects on domestic and foreign GDP as compared to euro area and Japan credit supply shocks. Domestic and foreign credit and equity markets also respond to the credit shocks, and exchange rate responses are consistent with a flight to quality to the US dollar.

Xu (2012) also checked the role of bank credit on modeling and forecasting business cycle fluctuations and concluded that the incorporation of credit provides significant improvements in modeling and forecasting output growth, changes in inflation and long-run interest rates, for countries with a developed banking sector. Using GIRF the author found strong evidence of spillovers of the US credit shocks to the euro area, Japan, and other industrialized economies. On the other hand, Pesaran, Schuermann, and Treutler (2006) proposed a model for exploring credit risk diversification across industry sectors and across different countries or regions using a GVAR model accounting for about 80% of world output.

Monetary union membership counterfactual scenarios were presented by Pesaran, Smith, and Smith (2007) and by Dubois, Hericourt, and Mignon (2009). Pesaran, Smith, and Smith (2007) presented a counterfactual experiment of the UK's and Sweden's decisions not to join the EMU and concluded that output could have been higher and prices lower in the UK and in the euro area as a result of that entry. Dubois, Hericourt and Mignon (2009) also investigated counterfactual scenarios of a monetary union membership showing that the national monetary unification led to lower interest rates and higher output in most euro area countries when compared to a situation in which national monetary policies would have followed a German-type one. If British monetary preferences after September 1992 had beenwere adopted, this would have promoted higher interest rates, depreciation of national exchange rates, and higher output in most euro area countries.

Although oil prices are included in the majority of these models as a global variable, i.e., as an important observed common factor, Cashin, Mohaddes, Raissi, and Raissi (2012)

employed a set of sign restrictions on the generalized impulse responses of a GVAR model to distinguish supply-driven from demand-driven oil price shocks and to study the time profile of their macroeconomic effects in different countries. Their results indicate that the supply-driven oil price shock economic consequences are very dissimilar from those of an oil-demand shock driven by global economic activity, and differ for oil-importing countries compared to energy exporters. On this same subject, Chudik and Fidora (2012) found that supply shocks tend to have a stronger impact on emerging economies' real output as compared to mature economies, have a negative impact on real growth in oil-exporting economies, and tend to cause an appreciation of oil exporters' real exchange rates, but also lead to an appreciation of the US dollar.

Regarding inflation, Galesi and Lombardi (2009) studied the short-run inflationary effects of oil and food price shocks, concluding that they are felt mostly in developed countries, while less sizeable effects are revealed in emerging economies. Anderton, Galesi, Lombardi, and di Mauro (2010) calculated the impact of increased imports from low-cost countries on manufacturing import prices and estimated Phillips curves to explore whether the inflationary process in OECD countries changed over time. Overall, the authors found that there are various significant pressures on global trade prices and labor associated with structural factors.

The role of the US as a potentially globally dominant economy was investigated by Dées and Saint-Guilhem (2011). These authors concluded that countries with a large trade exposure to the US economy have a relatively greater sensitivity to US developments and also that the role of the US in the global economy has changed over time. Chudik and Smith (2013) extended the literature on the role of a globally dominant economy, once again the US, by comparing two models: one that treats the US as a globally dominant economy, and a standard version of a GVAR model that does not separate the impact of the US variables from the cross-section average of foreign economies, as in Dées, di Mauro, Pesaran, and Smith (2007).

From a global imbalances perspective, Bettendorf (2012) showed that real GDP is a relatively unimportant variable compared to real exchange and interest rates and to the oil price, and also provides a counterfactual analysis of the US trade balance. Bussière, Chudik, and Sestieri (2012) studied the effects of demand shocks and shocks to relative prices on global imbalances, concluding that changes in domestic and foreign demand have a much stronger effect on trade flows than changes in relative trade prices.

To the best of our knowledge, the GVAR approach has not yet been used to test for cross-border spillover effects of an increase in public and private investment in the euro area.

4.3. Econometric Methodology

GVAR models (Pesaran et al., 2004) are designed to capture the dynamics of a large part of the world economy by linking country-specific VAR models to each other using, for instance, trade weights. Though GVAR models are linear, they allow for a range of different interdependencies between variables and countries, such as theory consistent long-run relationships, short-run spillover effects and cross-sectional dependence on the error structure. Thus, they offer a fair degree of flexibility in modeling business-cycle dynamics of the world economy in a coherent fashion.

4.3.1 Structure of the model

Basically a GVAR model consists of a number of country-specific models that are combined to form the global model. In a first step the country-specific models are estimated individually under certain restrictions. In a second step the GVAR model is solved by combining the individual models.

For a brief illustration of the approach, consider a sample of $N + 1$ different countries. Let x_{it} be the k_i x 1 vector of domestic random variables for country $i = 0, \dots, N$ and time $t = 1, \dots, T$. For each country, we consider a VAR model that is augmented with a set of (weakly exogenous) foreign variables and which is defined as VARX*.

To simplify the notation but without loss of generality, we restrict our exposition to a VARX*(1,1) specification , i.e.,

$$x_{it} = a_{i0} + a_{i1}t + \Phi_{i1}x_{i,t-1} + \Lambda_{i0}x_{it}^{*} + \Lambda_{i1}x_{i,t-1}^{*} + \varepsilon_{it} \qquad (1)$$

where a_{i0}, a_{i1}, Φ_{i1}, Λ_{i0}, and Λ_{i1} are properly sized coefficient matrices measuring the impact of deterministic components, lagged domestic variables, and contemporaneous and lagged foreign variables, respectively.

Foreign variables are computed as a weighted average of domestic variables of all other countries based on trade weights $x_{it}^{*} = \sum_{j=0}^{N} w_{ij}\, x_{jt}^{*}$, under the restriction that $w_{ii} = 0$ and $\sum_{j=0}^{N} w_{ij} = 1$. The assumption that x_{jt}^{*} is weakly exogenous at the individual country level reflects the belief that most countries are small relative to the world economy.

Moreover, most existing papers on GVAR models make the assumption that the co-variance matrix of ε_{it} is fixed.

Pesaran et al. (2004) show how the $N + 1$ country models can be combined to yield the GVAR representation. Defining a $(k_i + k_i^{*})x1$ vector $z_{it} = (x_{it}', x_{it}^{*'})'$, collecting all contemporaneous terms on the left-hand side and ignoring deterministic terms for notational simplicity, (1) can be write equation as:

$$A_i z_{it} = B_i z_{i,t-1} + \varepsilon_{it} \tag{2}$$

where $A_i = \left(I_{k_i} - \Lambda_{i0}\right)$ and $B_i = (\Phi_{i1}, \Lambda_{i1})$ are both k_i x $(k_i + k_i^{*})$ dimensional matrices. We collect all endogenous variables in a kx1 global vector $X_t = (x_{0t}', x_{1t}', \ldots x_{Nt}')'$, where $k = \sum_{i=0}^{N} k_i$ is the total number of endogenous variables in the GVAR. By defining a suitable $(k_i + k_i^{*})$ x k linking matrix W_i, it is possible to rewrite $\boldsymbol{z_{it}}$ exclusively in terms of X_t and W_i. More specifically, the linking matrix is set such that the following equality holds

$$z_{it} = W_i X_t \tag{3}$$

Inserting (3) into (2) and stacking the models for all countries yields

$$GX_t = HX_{t-1} + \varepsilon_t$$

where $G = ((A_0 W_o)', (A_1 W_1)', \ldots, (A_N W_N)')'$, $H = ((B_0 W_o)', (B_1 W_1)', \ldots, (B_N W_N)')'$ and $\varepsilon_{t=} \coloneqq (\varepsilon_{0t}', \ldots, \varepsilon_{Nt}')'$.

Multiplying from the left by G^{-1} yields the reduced-form GVAR representation:

$$X_t = FX_{t-1} + e_t \tag{4}$$

where $F := G^{-1}H$ and $e_t := F = G^{-1}\varepsilon_t$. Equation (4) resembles a standard first-order reduced form VAR. The structure of the VARX* model induces restrictions on the parameter matrix F. In addition to the restrictions imposed on F, the model structure has important implications for the specific form of the variance-covariance matrix of e_t, Σ_{et}. In the present application, Σ_{et} is a positive definite matrix, given by:

$$\Sigma_{et} = G^{-1}\Sigma_{et}G^{-1}$$

where Σ_{et} is a block-diagonal matrix that consists of the country-specific variance-covariance matrices Σ_{it}. The block-diagonality of Σ_{et} is predicated by the fact that the weakly exogenous variables inclusion accounts for cross-country correlation and renders the estimation problem of the $N + 1$ submodels parallel, providing significant computational advantages.

4.4. Estimation

4.4.1 Data

Quarterly data were used from 1997Q1 to 2014Q4 for 16 countries: Austria (AT), Belgium (BE), Denmark (DK), Finland (FI), France (FR), Germany (DE), Greece (GR), Ireland (IE), Italy (IT), Netherlands (NL), Portugal (PT), Spain (ES), Sweden (SE), United Kingdom (UK), United States (US), and Japan (JP). The GVAR model includes three country-specific variables for each country's VARX* model: Private Investment ($priv_{it}$), Public Investment (pub_{it}), and GDP (y_{it}).

All variables are presented at constant prices and in growth rates of the original values. GDP was transformed into real values using the GDP price deflator. GDP and GDP price deflator data are obtained from the OECD. Yearly private investment and private investment price deflator's data were collected from AMECO. To transform these data from annual to quarterly, we took advantage of the Ecotrim program. The gross fixed capital formation (GFCF) and the gross fixed capital formation price deflator from the OECD database were used as indicators. The data for the annual public investment and the annual public Investment price deflator were also collected from AMECO. Once again, we used the Ecotrim program, but in this case no indicator was applied.

A simple average was applied to oil price data to transform the series from a monthly to a quarterly frequency. The source for the oil price data was the IMF cross-country macroeconomic statistics.

Foreign-specific variables were constructed using trade-based weights that were fixed over time and computed using the average of exports and imports cross-country data, for the period 1999-2014. The data source for the weight matrix was the IMF.

Finally, we also used, for comparison purposes, the average Purchasing Power Parity GDPs of all countries included in this model over the 2000-2015.

All models include the country-specific foreign-variables, y_{it}^{*}, $priv_{it}^{*}$ and pub_{it}^{*} and the log of the oil price (op_t) as weakly exogenous variables, with the exception of the US model. In the case of the US, the price of oil was included as an endogenous variable.

4.4.2 Trade Weights

The country-specific foreign variables are constructed using a time-fixed weight matrix. The trade shares are given in the 16 X 16 trade share matrix provided in Table 4.1 of the Appendix, each column containing the 1999-2014 shares of exports and imports. Most weights are small with some exceptions, namely Austria *vis-à-vis* Germany (50.5%), and Japan *vis-à-vis* UK (62.7%).

4.4.3 Unit Root Tests

A series of unit root tests was used to investigate whether or not the macroeconomic variables used are integrated processes. Tables 4.2 and 4.3 of the Appendix report results for the traditional Augmented Dickey-Fuller (ADF) tests on levels with trend and no trend, first and second differences, for all domestic and foreign variables. The lag order of the ADF test statistics is determined by the minimization of the Akaike Information Criterion (AIC). The maximum lag allowed was 4. The Weighted Symmetric DF tests were also computed based on related regressions with the corresponding lag order chosen by AIC. Results of these tests on levels and, first and second differences are reported in Table 4.4 of the Appendix (domestic variables) and in Table 4.5 of the Appendix (foreign variables). Both ADF and Weighted Symmetric DF test results indicate that the unit root null hypothesis cannot be rejected for most variables in most countries at the 5% significance level, i.e. most variables are I(1).

4.4.4 Estimation of the Country-specific

The presence of non-stationary variables makes the traditional OLS regressions in levels no longer valid. However taking into account that the majority of the variables have a unit root, each country-VARX* model was estimated individually with the restriction that both foreign and global variables are weakly exogenous variables. In the current application, the reduced rank regressions are used in the case of unrestricted intercepts and no trends (e.g. case III in Pesaran, Shin and Smith 2000). Table 4.8 presents the number of cointegration relationships in the individual VARX* models. We used the critical values obtained in Mackinnon, Haug and Michelis (1999).

4.4.5 Testing for Weak Exogeneity

Weak exogeneity of all foreign and global variables (x_{it}^{*}) is an important assumption of the VARX* model and it is required for the estimated country-specific VARX* models to be stacked together and solved as one system. Assuming that the variables are weakly exogenous, is basically considering that all countries are small economies with respect to the rest of the world.

Pesaran, Schuermann and Weiner (2004) provide three conditions that the model should fulfil so that all star variables can be assumed to be weakly exogenous: (i) the global model should be stable, (ii) all the weights used in the construction of the foreign-specific variables should be relatively small and (iii) the individual country-specific shocks are cross-sectionally weakly correlated. As further discussed in Pesaran, Shuermann and Weiner (2004), weak exogeneity assumption is also compatible with a certain degree of weak dependence across the errors. Whereas, according to Johansen (1992) and Granger and Lin (1995), the weak exogeneity assumption in cointegrating models imply no long run feedback from x_{it} to x_{it}^{*}, without necessarily ruling out lagged short run feedback between the two sets of variables. In this case, x_{it}^{*} is said to be 'long run forcing' forx_{it}, which directly implies that the error correction terms of the individual country VECMX* models do not enter the marginal model of x_{it}^{*}.

A formal test based on the weak exogeneity assumption for the country-specific foreign variables and the observed global variables can be conducted as described in Johansen (1992) and Harbo, Johansen, Nielsen and Rahbek (1998). It involves the computation of a joint significance test. In particular, for each ith element of $xit*$ the following regression is estimated:

$$\Delta x^{*}_{it,l} = \mu_{il} + \sum_{j=1}^{r_i} \gamma_{ij,l} ECM^{j}_{i,t-1} + \sum_{k=1}^{p_i} \phi_{ik,l}\, \Delta x_{i,t-k} + \sum_{m=1}^{q_i} \theta_{im,l} \Delta x^{*}_{i,t-m} + \varepsilon_{it,l}$$

where $ECM^{j}_{i,t-1}$, j = 1, 2, ..., are the estimated error correction terms, $_i$ is the number of cointegrating relations found for the i[th] country model; $\Delta x_{i,t-k}$, k = 1, …, pi, and $\Delta x^{*}_{i,t-m}$, m = 1, …, qi, are sets of lags of the first difference of the domestic and foreign variables, respectively, and p_i and q_i, are the lag orders of the domestic and foreign components of each i[th] country model. Hence, the test for weak exogeneity is an F-test of the joint null hypothesis that $\gamma_{ij,l} = 0$, j=1,2,…, r_i (see e.g. Galesi and Lombardi, 2009).

Table 4.6 presents weak exogeneity test results. The weak exogeneity assumption could not be rejected for the majority of variables considered. In fact, only 12 out of the 59 cases analyzed were found to be statistically significant at the 5% level.

4.4.6 Impact Elasticities

The coefficient estimates of the contemporaneous foreign variables in differences, also called impact elasticities, were obtained from the estimation of each country-VECMX* model. These estimates present the contemporaneous variation of a domestic variable caused by a one percent change in its corresponding foreign-specific counterpart allowing to identify co-movements among variables across different countries. The results can be found in table 4.7.

4.4.7 Robustness of the GVAR results to time-varying weights

To test the robustness of the model results we performed different analyses. First, time-varying weights were computed based on a three-years wide rolling window so that possible changes in the trade profile of the countries were taken into account. Overall, we did not find significant changes in the results. Secondly, we estimated the model only for the period between 1997Q1 until 2007Q4, excluding in that matter the financial crisis

from the sample.[2] Once again, the results remained mainly the same. These results are available from the authors upon request.

4.5. Dynamic Analysis

The dynamic properties of our GVAR were tested by means of the GIRFs. The concept of GIRFs was introduced by Koop, Pesaran, and Potter (1996) and applied to the VAR analysis by Pesaran and Shin (1998). In a GVAR context of multi-countries and several variables, GIRFs are preferable to the standard IRFs proposed by Sims (1980), which assume orthogonal shocks. It is known that if IRFs are calculated using different orders of variables, then the shape of the IRFs will be different. In fact, if the model is estimated using a reduced number of variables, a relationship between the variables can be inferred based on economic theory. However, this approach is not valid for the GVAR model given that it typically contains a large number of variables. Moreover, traditional IRFs are difficult to use in a GVAR since there is no realistic way to order the countries in the model.

4.5.1 Generalized Impulse Response Functions

In this chapter, we analyze the consequences of shocks to both public and private investment in a central European economy (Germany) and in a peripheral one (Portugal).

The GIRFs of the shocks analyzed are plotted in Figures 4.1 through 4.12. For each country, the graphs show the dynamic response of each variable over a simulation horizon of 20 quarters, including the confidence intervals at the 90 percent significance level computed with 1000 bootstrap replications of the GVAR model.[3] We are aware that most of the responses appear to not be statistically significant. However, this is justified by the fact that the model was estimated using only 72 quarterly observations.

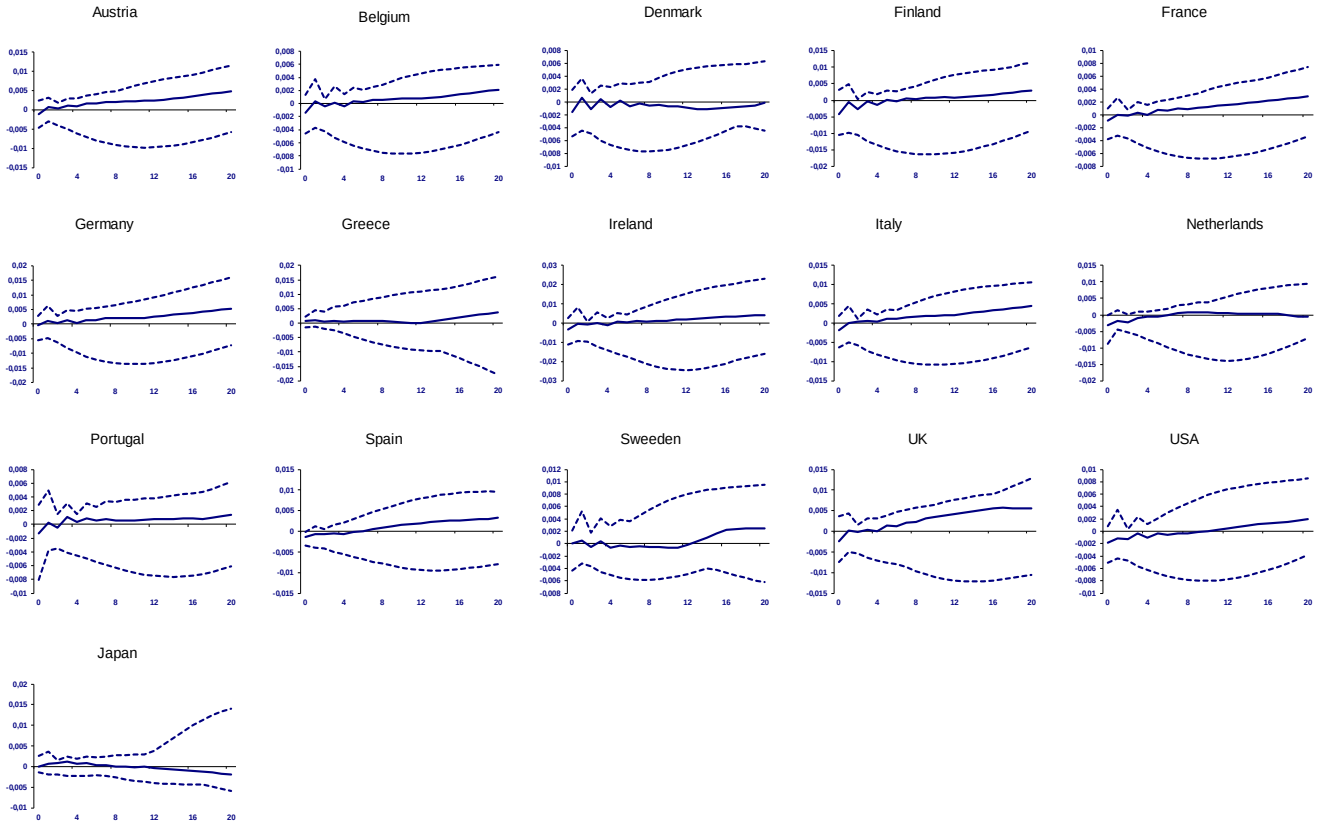
[2] Results for the 1997Q1-2007Q4 sample are available upon request.
[3] For more details on the bootstrap technique, see Kreiss (1992), Bühlmann (1997), and Bickel and Bühlmann (1999).

4.5.1.1 Shock to Public Investment

As a first exercise, and as mentioned above, we investigate if countries with a surplus account, such as Germany, can help boost weaker European economies through cross-country spillover effects of an increase in public investment.

The graphs in Figures 4.1 to 4.3 include the GIRFs from a one standard error positive shock to Germany's public investment[4].

Figure 4.1. GIRFs of GDP to a 1 s.e. positive shock to Germany's Public Investment



[4] The GVAR model is a linear model, so resizing the model is straightforward.

Figure 4.2. GIRFs of Private Investment to a 1 s.e. positive shock to Germany's Public Investment

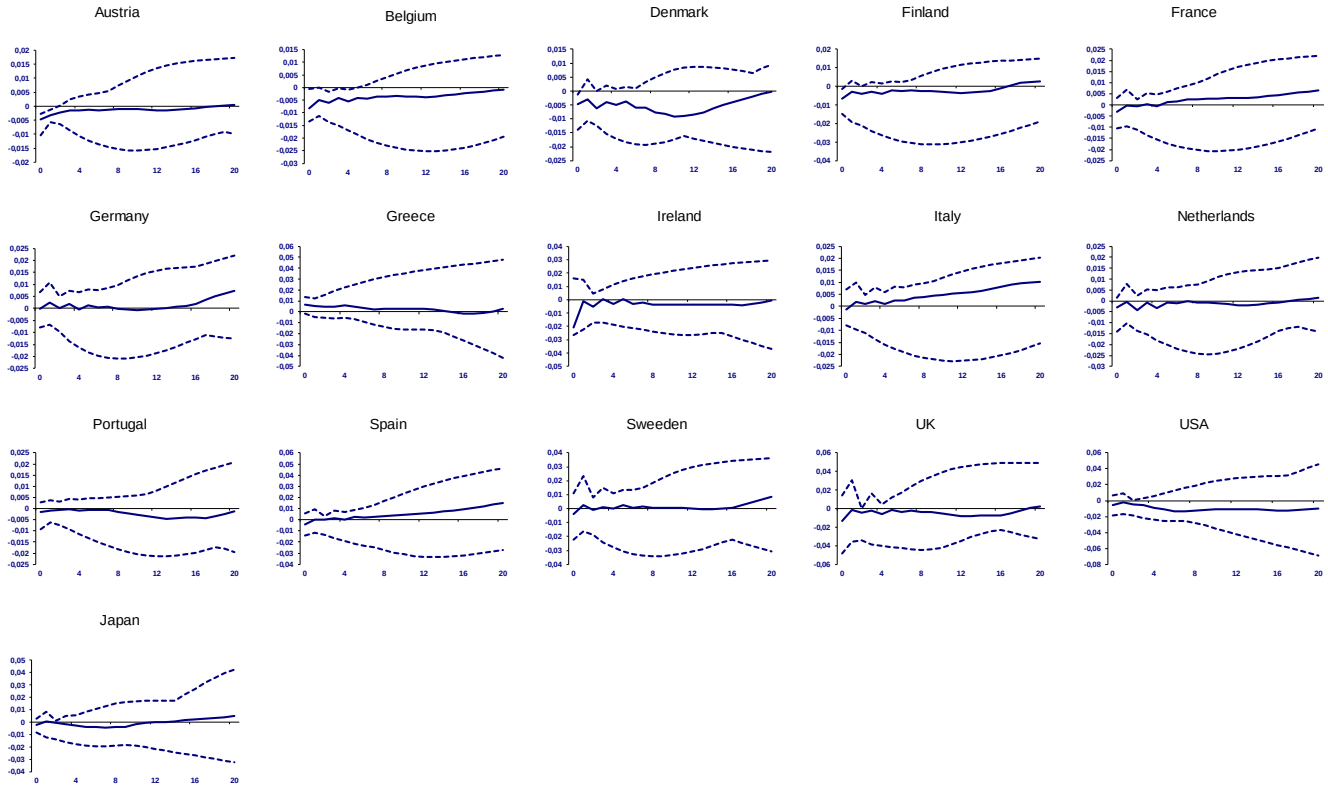
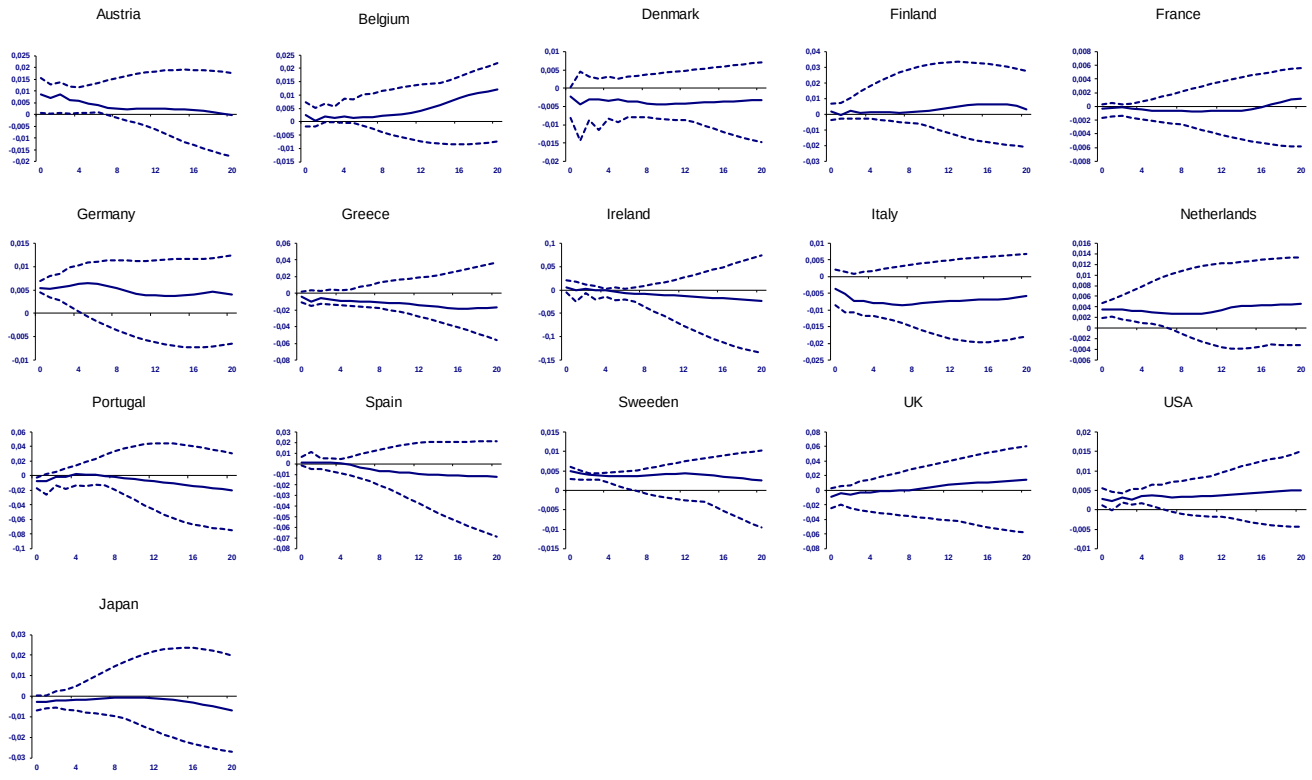


Figure 4.3. GIRFs of Public Investment to a 1 s.e. positive shock to Germany's Public Investment



A positive response is estimated in almost all countries' GDP after the second quarter following a positive standard error unit shock to public investment in Germany. However, these increases do not appear to be statistically significant, not even in Germany itself. Private investment reacts negatively immediately after this shock in Austria and Belgium. Specifically, Austria's private investment decreases an average of 0.003% in the first four quarters following the shock, and Belgium's private investment 0.005%. In Germany the reaction of private investment is positive, which suggests a crowding-in effect. However it is not statistically significant, as is also the case for the remaining countries. Public investment reacts positively in Austria, Germany, Netherlands, and Sweden, with the average response for the first six quarters after the shock being 0.006% in Austria and Germany, 0.003% in Netherlands, and 0.004% in Sweden. On the contrary, a stimulus in Germany's public investment has a negative impact in Portugal of 0.008%, but only in the quarter immediately following the shock. As expected, as the oil price is an exogenous variable to all countries, except for the USA, the impact of a shock to public investment in Germany is not statistically significant. (Figure 4.13 of the Appendix).

Figure 4.4. GIRFs of GDP to a 1 s.e. positive shock to Portugal's Public Investment

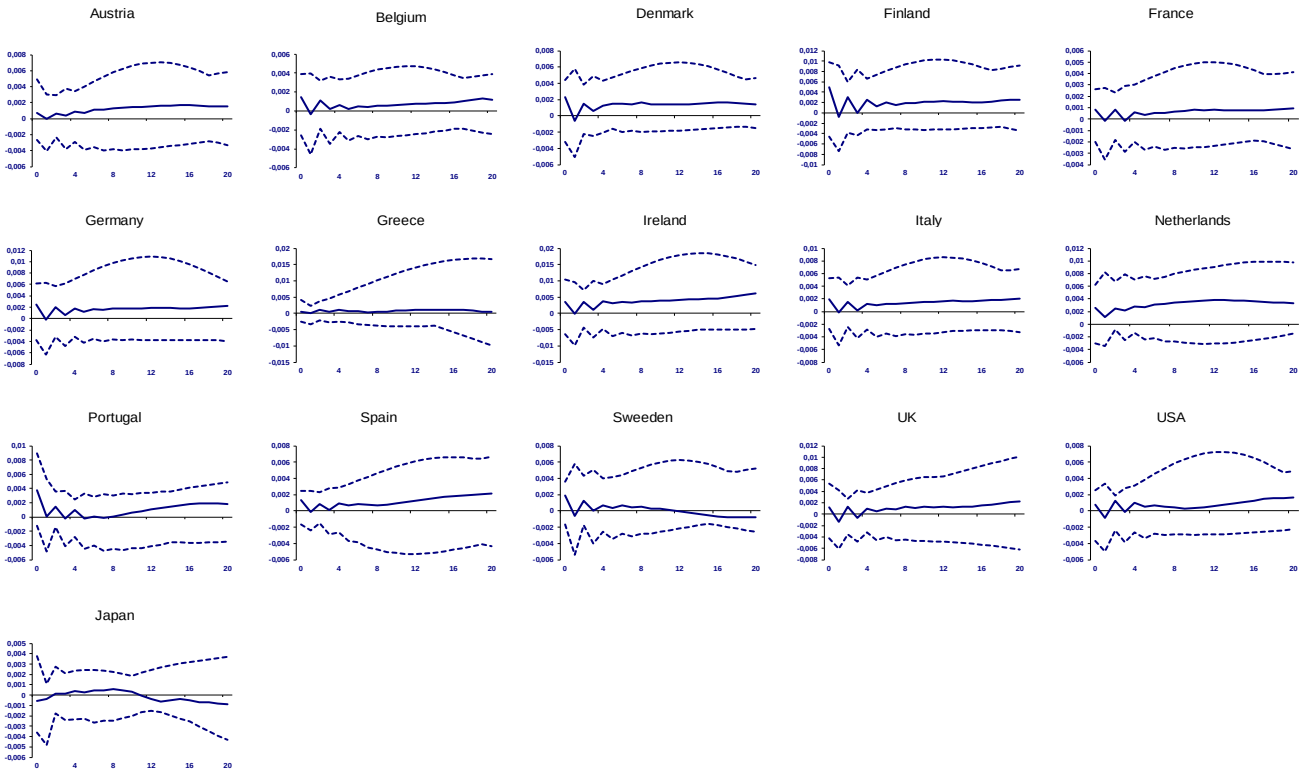


Figure 4.5. GIRFs of Private Investment to a 1 s.e. positive shock to Portugal's Public Investment

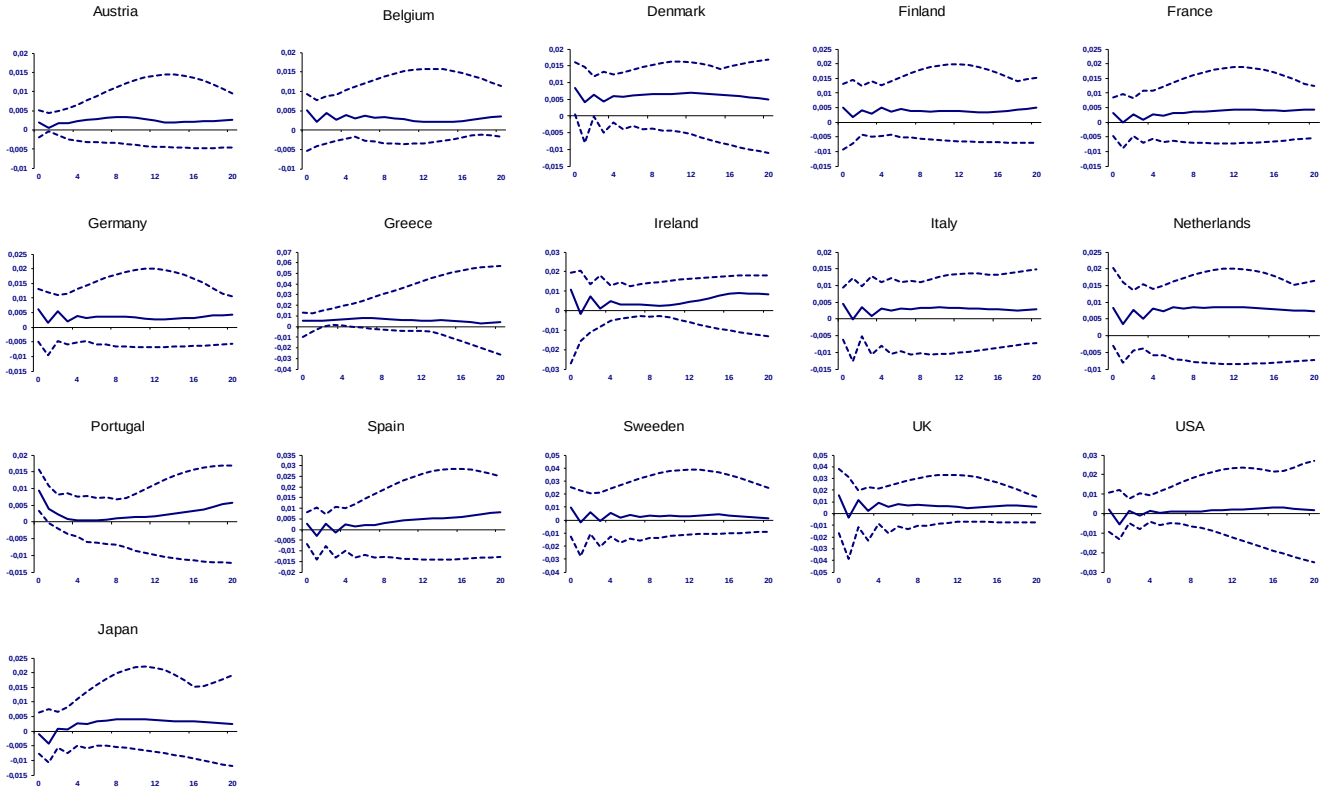
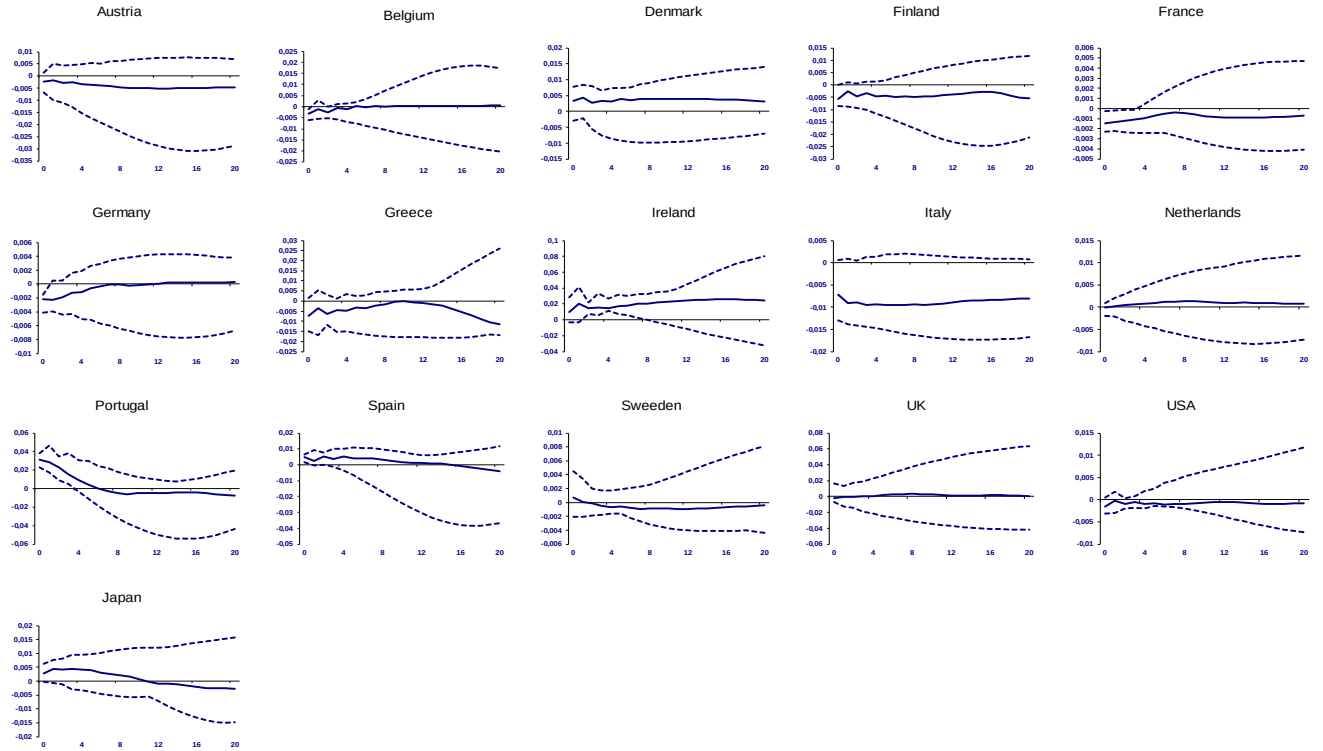


Figure 4.6. GIRFs of Public Investment to a 1 s.e. positive shock to Portugal's Public Investment

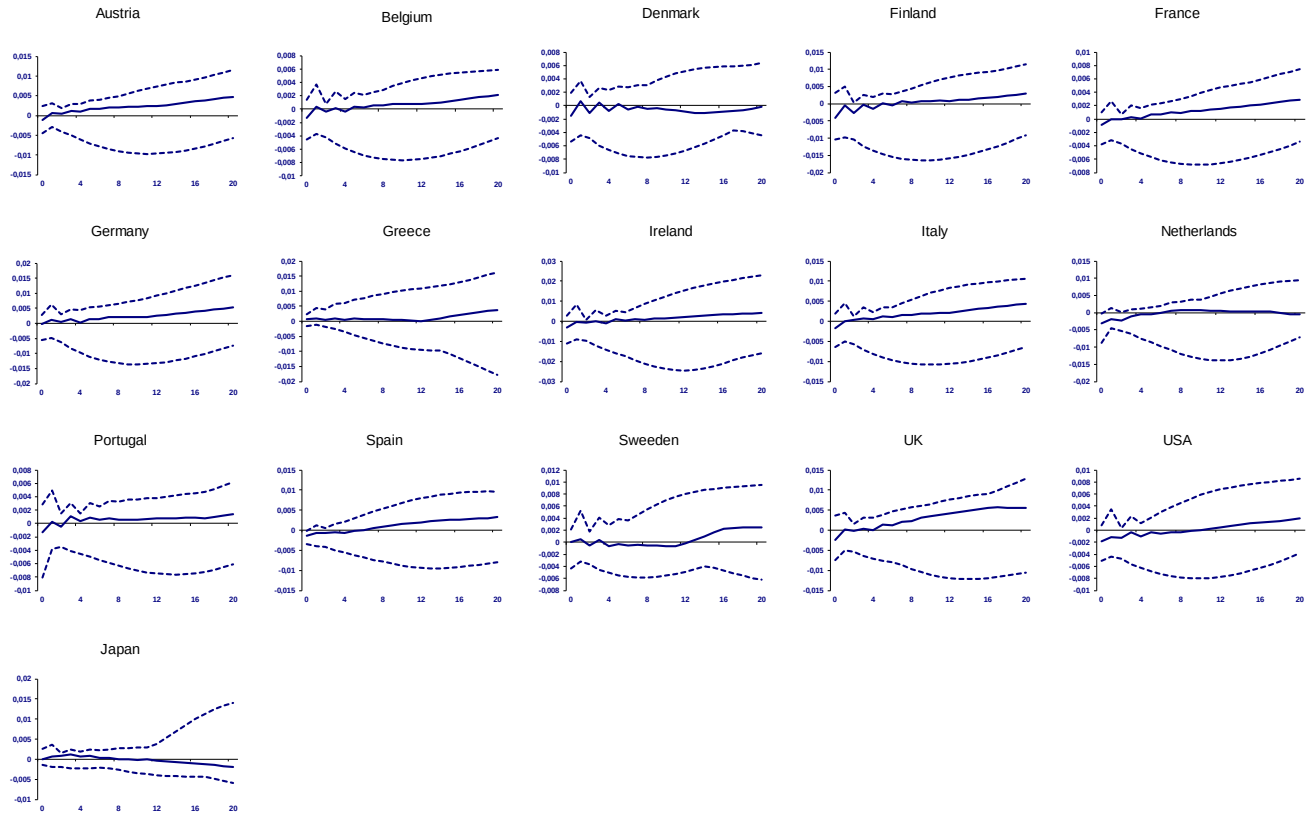


Concerning the effects of a positive impulse of one standard error in public investment in a small open economy such as Portugal, as one would probably expect, GDP does not react in a statistically significant way in any foreign country and also not in Portugal. (Figure 4.4). Figure 4.5 shows that in relation to private investment, it responds positively and in a statistically significant way only in Portugal, which points to a crowding-in effect in this economy, at least in the short run. In relation to public investment, it reacts in a negative way in the first quarter immediately after the shock in Germany and Belgium, decreasing also in France 0.001% on average in the first three quarters after the impulse. On the other hand, it has a positive impact in Spanish public investment of 0.004%, on average, in the first three quarters after the impulse and of 0.03% in the first four quarters in the Portuguese public investment (Figure 4.6). Oil prices increase, but this is not statistically significant (Figure 4.14 of the Appendix).

4.5.1.2 Shock to Private Investment

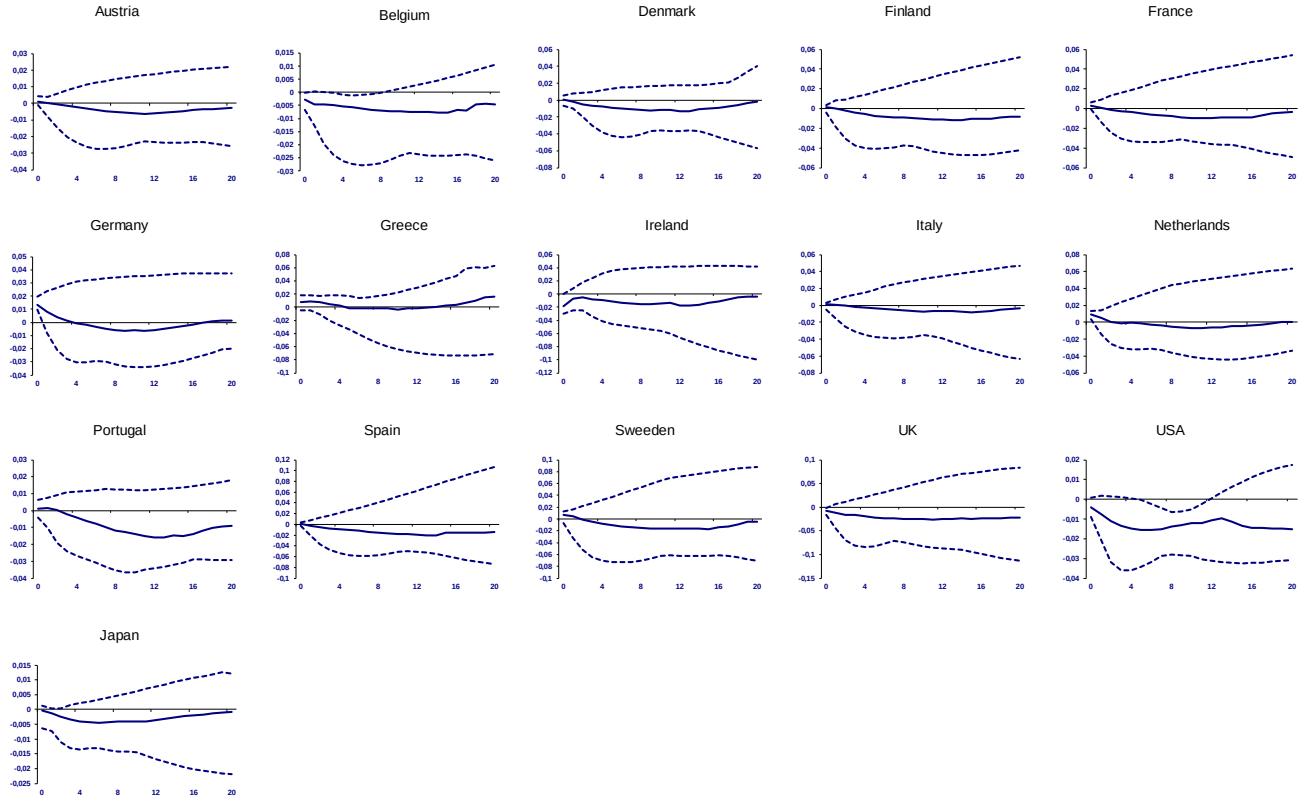
To investigate the role of Germany's private investment, we show in Figures 4.7 to 4.9 the GIRFs from a one standard error positive shock to this variable.

Figure 4.7. GIRFs of GDP to a 1 s.e. positive shock to Germany's Private Investment



GDP it does seem to not react in a statistically significant manner in any of the economies analyzed. (Figure 4.7). Figure 4.8 presents the GIRFs of private investment after a shock in Germany's private investment. In fact, Germany's private investment positive innovations do not impinge significantly on other countries' private investment, except in the case of neighboring economies, namely, Netherlands and Sweden and Germany itself.

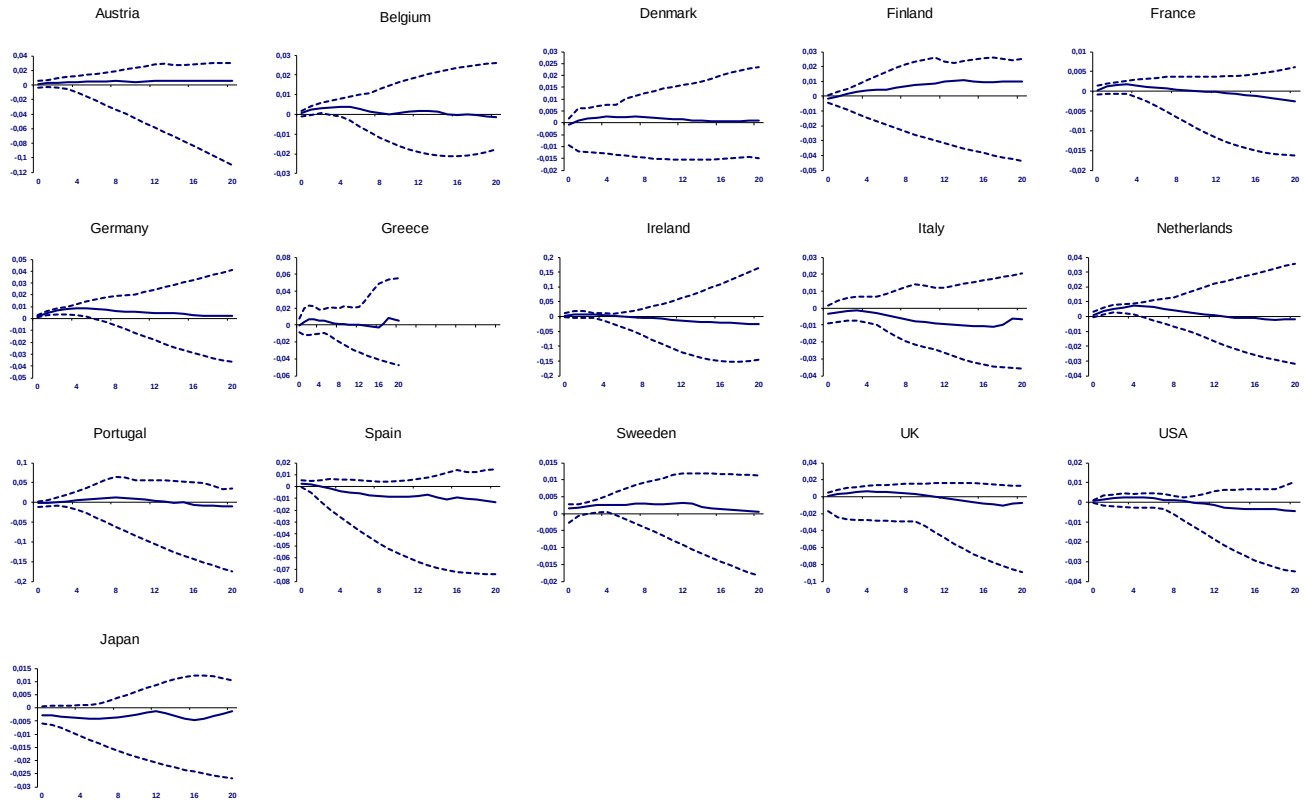
Figure 4.8. GIRFs of Private Investment to a 1 s.e. positive shock to Germany's Private Investment



With regard to private investment, it stimulates public investment in Germany and in neighboring countries such as Netherlands and Sweden. In particular, Germany's public investment rises by 0.007% on average in the first five quarters after a one standard error positive shock to private investment in Germany. While the effect is not significant immediately following the shock, it becomes statistically significant from the second to the fourth quarter, increasing on average 0.006%. Sweden's public investment reacts in a statistically significant way in only the third and fourth quarters, increasing on average

0.002% (Figure 4.9). As can be seen in Figure 4.15 of the Appendix, the oil price does not respond in a statistically significant way.

Figure 4.9. GIRFs of Public Investment to a 1 s.e. positive shock to Germany's Private Investment



The results from a one standard error impulse in Portugal's private investment are presented in graphs 4.10 to 4.12. A positive shock to private investment in Portugal does not seem to stimulate GDP in any of the economies considered in a significant manner (Figure 4.10). As can be seen in Figure 4.12, private investment raises Portuguese public investment by 0.013%, on average, in the seven periods following the shock. Portuguese private investment positive innovations do not impinge significantly on other countries' private investment. (Figure 4.11). Concerning the impact on private investment, it shows a statistically significant response only in Portugal. As expected, this shock has no impact on oil prices (Figure 4.16 of the Appendix).

Figure 4.10. GIRFs of GDP to a 1 s.e. positive shock to Portugal's Private Investment

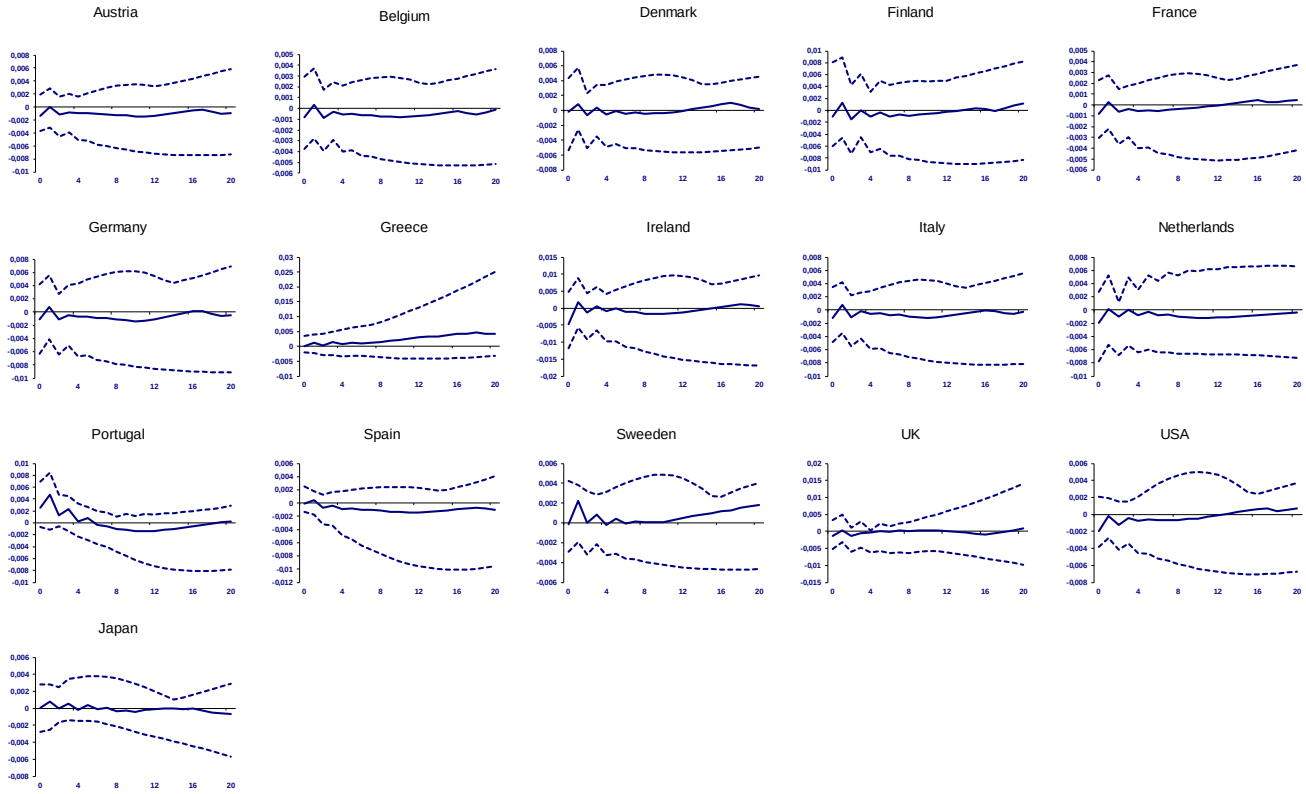


Figure 4.11. GIRFs of Private Investment to a 1 s.e. positive shock to Portugal's Private Investment

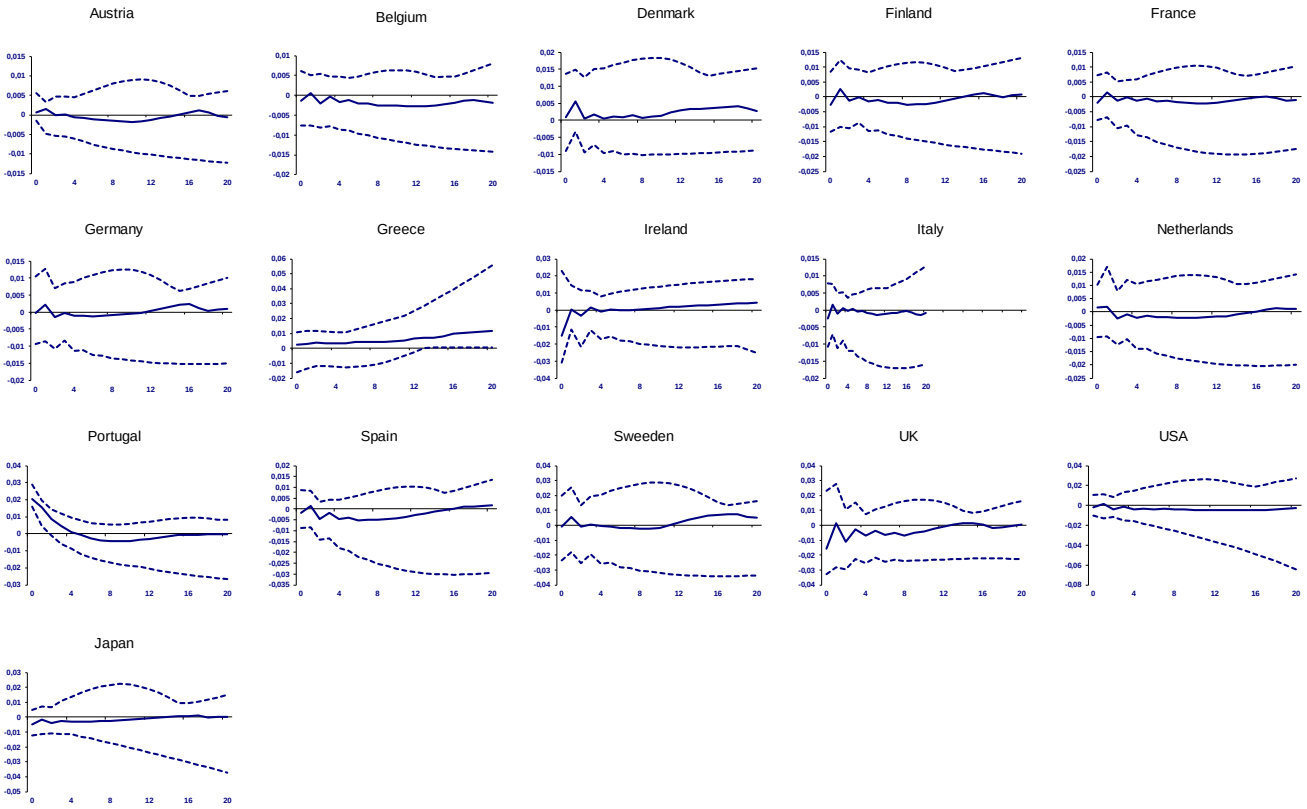
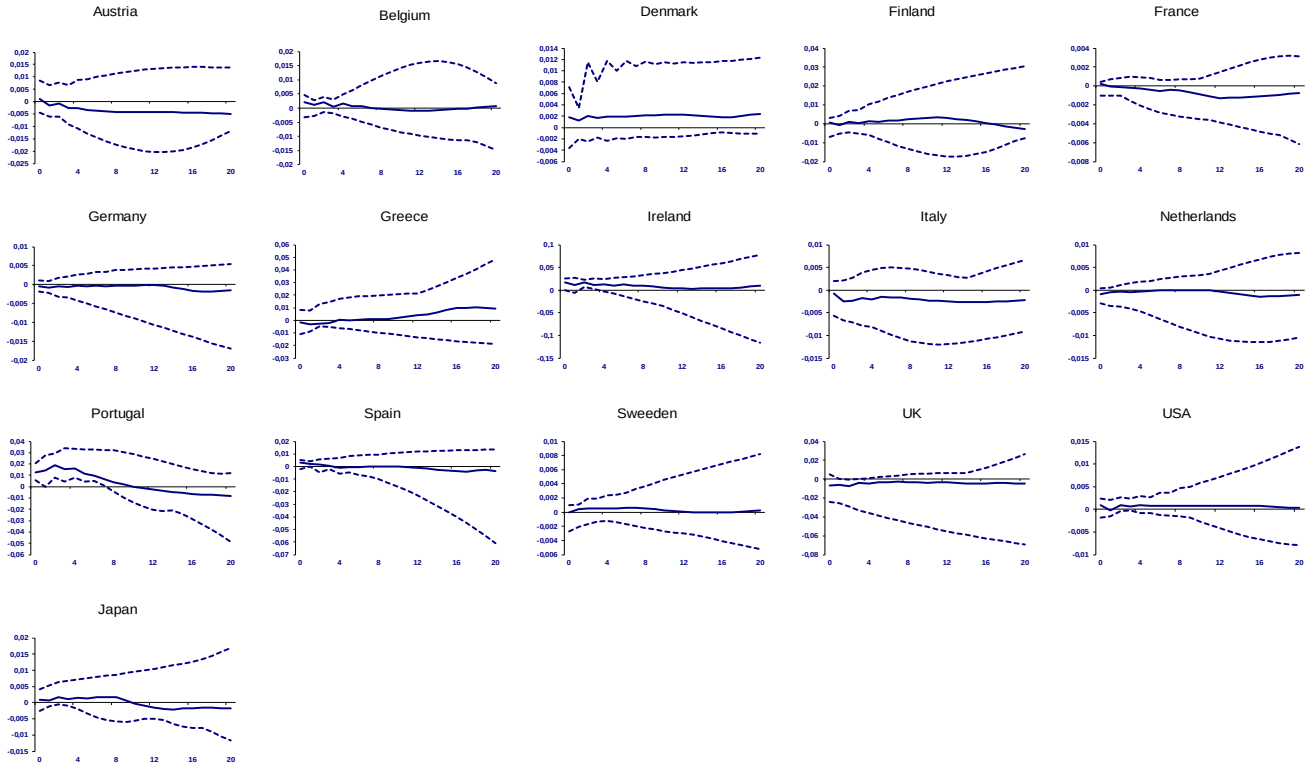


Figure 4.12. GIRFs of Public Investment to a 1 s.e. positive shock to Portugal's Private Investment



4.6. Conclusions

Based on a GVAR technology, and in particular on the Generalized Impulse Response Functions, we investigated the impact of innovations to both public and private investment in Germany, a central European economy that is one of the major surplus countries in the world, and in Portugal, a peripheral European economy. Quarterly data were used from 1997Q1 to 2014Q4 for 16 countries. The GVAR model includes three country-specific variables for each country's VARX* model: Private Investment $(priv_{it})$, Public Investment (pub_{it}), and GDP (y_{it}). Foreign-specific variables were constructed using trade-based weights that were fixed over time and computed using the average of exports' and imports' cross-country data, for the period 1999-2014.

Our findings suggest a positive response (with a two quarter delay) in almost all countries' GDP to a public investment shock in Germany. However, these increases do not achieve statistical significance, not even in Germany itself. Private investment reacts negatively and immediately after this shock in Austria and Belgium. In Germany we find evidence of a crowding-in effect, as the reaction of private investment is positive. However, it is not statistically significant, which is also the case for the remaining

countries. Following a shock to public investment in Germany, public investment increases in neighboring countries such as Austria, Netherlands, and Sweden. On the contrary, a stimulus in Germany's public investment has a negative impact on Portuguese public investment but only in the quarter immediately after the shock.

Concerning a similar shock in a small open economy such as Portugal, GDP does not react in a statistically significant way in any foreign country and also not in Portugal itself. Regarding private investment, it does respond positively and in a statistically significant way, but in Portugal only, pointing to a crowding-in effect in this economy, at least in the short run. Public investment reacts in a negative way in the first quarter immediately after the shock in Germany and Belgium, decreasing also in France in the first three quarters after the impulse. On the contrary, it shows a positive impact on Spanish and Portuguese public investment.

We also find evidence that after an innovation in Germany's private investment, GDP does not reacting in a statistically significant way.This shock shows also a positive effect in public investment in Germany and in neighboring countries such as the Netherlands and Sweden, pointing to a crowding-in effect. A one standard error impulse in Portuguese private investment does not seem to stimulate GDP significantly in any of the economies considered, as one might expect from a small open economy. This shock shows a positive impact in Portuguese public investment, pointing also to a crowding-in effect. However, it does not seem to influence other countries' private investment.

The main conclusion from this study is that even if Germany increases its public investment it will not have the desired positive impact on peripheral economies. In fact, one finds statistically significant cross-border effects mainly in neighboring countries, and the magnitude of those impacts is modest.

Finally, concerning crowding-in and crowding-out effects, we find that only Germany's private investment is able to crowd-in public investment, while public investment does not seem to have any impact on Germany's private investment. In the case of Portugal we find that both public and private investment show a crowding-in effect.

4.7 Appendix

Table 4.1. Trade weights

	AT	BE	DK	FI	FR	DE	GR	IE	IT	NL	PT	ES	SE	UK	US	JP
AT	0	0.013	0.011	0.019	0.014	0.091	0.019	0.006	0.040	0.018	0.008	0.012	0.015	0.010	0.009	0.005
BE	0.024	0	0.023	0.030	0.111	0.081	0.030	0.165	0.048	0.169	0.043	0.041	0.072	0.083	0.077	0.030
DK	0.010	0.010	0	0.015	0.010	0.026	0.015	0.008	0.012	0.017	0.010	0.009	0.108	0.008	0.016	0.003
FI	0.008	0.008	0.039	0	0.007	0.016	0.015	0.005	0.008	0.013	0.007	0.005	0.100	0.008	0.010	0.006
FR	0.070	0.222	0.065	0.079	0	0.166	0.079	0.072	0.200	0.118	0.160	0.265	0.078	0.095	0.125	0.035
DE	0.505	0.246	0.251	0.229	0.240	0	0.229	0.099	0.228	0.330	0.175	0.161	0.164	0.150	0.163	0.093
GR	0.008	0.008	0.009	0.063	0.012	0.011	0	0.005	0.030	0.009	0.005	0.014	0.007	0.005	0.008	0.004
IE	0.005	0.008	0.017	0.005	0.010	0.009	0.005	0	0.007	0.011	0.006	0.007	0.008	0.029	0.103	0.007
IT	0.132	0.065	0.044	0.233	0.127	0.105	0.233	0.044	0	0.066	0.050	0.121	0.049	0.049	0.056	0.025
NL	0.030	0.160	0.068	0.050	0.062	0.109	0.050	0.052	0.042	0	0.050	0.047	0.081	0.116	0.113	0.069
PT	0.006	0.008	0.007	0.014	0.020	0.014	0.014	0.005	0.018	0.010	0	0.126	0.008	0.005	0.010	0.003
ES	0.036	0.043	0.037	0.015	0.127	0.068	0.063	0.040	0.104	0.043	0.320	0	0.039	0.031	0.060	0.017
SE	0.018	0.019	0.185	0.020	0.019	0.035	0.020	0.014	0.017	0.025	0.015	0.013	0	0.016	0.031	0.008
UK	0.076	0.073	0.086	0.102	0.096	0.125	0.102	0.235	0.124	0.050	0.058	0.056	0.124	0	0.193	0.627
US	0.058	0.106	0.125	0.118	0.122	0.122	0.118	0.222	0.099	0.114	0.090	0.109	0.122	0.169	0	0.067
JP	0.016	0.012	0.032	0.007	0.023	0.024	0.007	0.029	0.024	0.009	0.005	0.012	0.024	0.226	0.024	0

Note: Trade weights are displayed in each column by country, as shares of exports and imports in 1999-2014. Columns, but not rows, sum up to one. The countries considered in the analysis are: Austria (AT), Belgium (BE), Denmark (DK), Finland (FI), France (FR), Greece (GR), Ireland (IE), Italy (IT), Netherlands (NL), Portugal (PT), Spain (ES), Sweden (SE), United Kingdom (UK), United States (US), and Japan (JP). Source: IMF, Trade statistics

Table 4.2. Augmented Dickey-Fuller (ADF) Unit Root Test Statistic for Domestic Variables (Based on AIC Order Selection)

Domestic Variables	Critical Value	AT	BE	DK	FI	FR	DE	GR	IE	IT	NL	PT	ES	SE	UK	US	JP
y (with trend)	-3045	-1.93	-1.63	-2.38	-1.41	-1.96	-3.15	-1.50	-2.17	-163	-2.39	-2.03	-0.93	-2.25	-2.08	-2.03	-2.20
y (no trend)	-2.89	-2.6	-2.08	-2.24	-2.84	-2.67	-0.97	-1.80	-3.39	-2.14	-3.01	-2.83	-2.29	0.611	-1.37	-2.59	-1.14
Dy	-2.89	-4.17	-4.69	-4.12	-3.30	-3.09	-4.46	-1.88	-2.28	-2.54	-3.13	-3.37	-2.34	-4.72	-3.84	-2.18	-4.93
DDy	-2.89	-6.69	-6.94	-5.59	-10.19	-6.95	-8.51	-11.73	-7.77	-6.25	-7.44	-7.1	-8.82	-4.53	-5.47	-8.79	-6.63
ipub (with trend)	-3.45	-1.38	-1.99	-4.62	-4.16	-1.07	-2.08	-1.95	-1.12	-0.75	-1.62	-1.64	-6.36	-2.17	-1.11	-0.58	-1.31
ipub (no trend)	-2.89	-0.55	-0.89	-0.77	0.55	-2.65	-2.09	-2.37	-2.15	-1.71	-2.10	-1.30	-2.69	-0.19	-1.06	-1.65	-5.14
Dipub	-2.89	-4.28	-3.33	-3.34	-3.43	-3.73	-2.57	-2.60	-1.74	-2.93	-2.81	-2.53	-3.94	-4.57	-3.05	-1.30	-3.55
DDipub	-2.89	-5.64	-6.06	-2.95	-4.86	-4.09	-4.27	-4.39	-4.93	-14.08	-4.48	-4.87	-2.61	-4.96	-8.74	-1.89	-6.33
ipriv (with trend)	-3.45	-3.71	-1.99	-1.83	-1.15	-2.42	-3.84	-1.68	-1.59	-1.24	-3.01	-2.86	-2.02	-4.48	-2.35	-3.08	-2.90
ipriv (no trend)	-2.89	-3.51	-1.54	-1.73	-2.30	-2.99	-2.78	-1.34	-1.77	-1	-3.08	-1.39	-2.28	-1.82	-1.96	-2.66	-2.78
Dipriv	-2.89	-3.64	-4.58	-5.30	-3.12	-3.47	-4.25	-2.,94	-6.32	-3.28	-4.78	-3.04	-2.36	-4.52	-4.21	-2.88	-3.05
Ddipriv	-2.89	-13.2	-7.80	-8.24	-5.96	-5.41	-10.53	-5.78	-8.25	-5.59	-6.04	-13.13	-5.28	-8.89	-6.50	-5.77	-6.29

.

Table 4.3. Weighted Symmetric ADF unit root test statistics for domestic variables (Based on AIC Order Selection)

Domestic Variables	Critical Value	AT	BE	DK	FI	FR	DE	GR	IE	IT	NL	PT	ES	SE	UK	US	JP
y (with trend)	-3.24	-1.02	-0.93	-1.70	-0.42	-0.51	-3.15	-1.52	-0.24	-1.03	-0.20	-0.82	-1.20	-2.68	-1.88	-1.68	-2.50
y (no trend)	-2.55	112	1.23	0.14	0.84	119	0.50	-1.25	1.67	-0.74	0.26	0.13	-0.32	1.27	0.68	2.22	0.87
Dy	-2.55	-4.30	-4.63	-4.26	-3.19	-3.06	-4.58	-1.87	-1.90	-272	-2.94	-3.39	-2.59	-5.03	-4.08	-2.18	-5.22
DDy	-2.55	-7.00	-7.00	-5.32	-10.47	-7.16	-8.72	-12.00	-8.02	-6.55	-7.76	-7.35	-8.91	-5.06	-5.63	-8.82	-6.83
ipub (with trend)	-3.24	0.15	-1.63	-4.21	-3.70	-1.08	-1.07	-1.89	-1.53	-1.25	-1.89	-2.11	-4.51	0.61	-1.33	-0.84	-1.19
ipub (no trend)	-2.55	-0.89	1.28	-0.99	1.21	-1.68	-1.66	-1.78	-1.51	-132	-0.66	-2.39	-2.02	-1.36	-0.64	-0.78	-1.24
Dipub	-2.55	-1.16	-2.39	-3.71	-1.10	-1.72	-1.30	-2.83	-2.04	-3.19	-3.11	-1.46	-4.12	-0.72	-3.03	-1.62	-3.10
Ddipub	-2.55	-3.51	-2.95	-1.59	-1.24	-2.45	-1.87	-4.58	-5.18	-14.48	-4.69	-3.85	-2.73	-2.89	-9.13	-1.91	-0.80
ipriv (with trend)	-3.24	-3.39	-2.14	-1.12	-0.20	-1.25	-4.00	-1.38	-1.23	-0.51	-2.48	-1.55	-1.39	-4.55	-2.05	-2.48	-2.88
ipriv (no trend)	-2.55	-2.61	-0.21	-1.23	0.07	0.38	-2.55	-1.67	-0.96	-0.52	-2.20	-1.68	-1.11	-0.73	-2.20	-2.62	-2.27
Dipriv	-2.55	-3.87	-4.76	-4.99	-2.59	-3.62	-4.41	-3.06	-6.54	-3.52	-4.93	-2.,65	-2.40	-4.89	-4.19	-3.01	-3.21
Ddipriv	-2.55	-13.55	-7.93	-8.52	-6.19	-5.62	-10.78	-6.10	-8.63	-5.84	-6.09	-13.41	-5.09	-9.15	-6.75	-5.98	-6.58

Table 4.4. Augmented Dickey-Fuller (ADF) unit root test statistics for foreign variables (Based on AIC Order Selection)

Foreign Variables	AT	BE	DK	FI	FR	DE	GR	IE.	IT	NL	PT	ES	SE	UK	US	JP
ys (with trend)	-2.52	-1.83	-2.36	-1.86	-1.85	-1.97	-2.00	-2.05	-1.96	-2.39	-1.54	-2.05	-1.94	-2.21	-2.26	-2.12
ys (no trend)	-1.59	-2.11	-2.10	-2.34	-2.31	-2.93	-2.28	-1.98	-1.85	-1.91	-2.04	-2.17	-2.31	-2.56	-2.80	-2.10
Dys	-4.02	-3.64	-4.13	-3.68	-3.81	-3.33	-3.81	-3.61	-3.54	-3.86	-3.01	-3.51	-3.64	-4.20	-3.22	-3.74
DDys	-7.33	-7.22	-5.20	-6.67	-6.77	-5.95	-6.60	-6.27	-6.48	-6.77	-6.19	-6.41	-6.78	-7.63	-5.19	-5.69
ipubs (with trend)	-1.78	-1.12	-1.36	-0.11	-0.98	-0.05	-0.13	-0.20	-1.20	-1.73	-1.64	-0.96	-0.85	-4.75	-0.50	-0.77
ipubs (no trend)	-2.11	-2.39	-1.95	-2.19	-2.05	-1.96	-2.11	-1.67	-2.05	-2.06	-2.54	-1.83	-1.48	-2.06	-2.07	-1.28
Dipubs	-2.01	-1.74	-1.96	-1.81	-1.18	-1.34	-1.55	-1.77	-1.64	-1.42	-1.36	-1.45	-1.59	-2.87	-1.54	-2.79
Ddipubs	-6.27	-3.85	-4.02	-6.84	-3.68	-3.81	-6.95	-4.67	-3.88	-3.00	-287	-4.96	-7.51	-3.98	-4.27	-8.62
iprivs (with trend)	-3.65	-3.19	-3.42	-2.59	-2.65	-2.68	-2.74	-2.66	-2.73	-3.31	-2.56	-2.87	-2.64	-3.62	-2.31	-2.51
iprivs (no trend)	-3.65	-3.27	-3.38	-2.66	-2.69	-2.76	-2.75	-2.57	-2.82	-3.28	-2.71	-2.84	-2.68	-3.66	-2.42	-2.19
Diprivs	-4.18	-3.33	-3.94	-3.07	-3.26	-3.19	-3.46	-3.34	-3.10	-3.96	-2.98	-3.36	-3.26	-3.31	-3.70	-3.94
Ddiprivs	-5.10	-5.11	-4.98	-7.74	-5.26	-7.31	-5.52	-6.92	-4.91	-5.08	-5.87	-4.83	-5.10	-5.62	-8.60	-6.92

Table 4.5. Weighted Symmetric ADF unit root test statistics for foreign variables (Based on AIC Order Selection)

Foreign Variables	AT	BE	DK	FI	FR	DE	GR	IE	IT	NL	PT	ES	SE	UK	US	JP
ys (with trend)	-2.01	-0.78	-0.90	-1.17	-0.87	-0.44	-1.00	-1.41	-1.32	-1.46	-1.08	-1.03	-0.86	-0.84	-0.61	-1.41
ys (no trend)	0.61	1.07	1.61	0.78	0.98	1.11	0.88	1.00	0.73	0.98	0.59	0.76	0.95	0.39	1.19	0.76
Dys	-4.05	-3.40	-4.14	-3.60	-3.78	-3.15	-3.78	-3.56	-3.52	-3.88	-3.05	-3.38	-3.55	-4.01	-2.88	-3.88
DDys	-7.50	-6.97	-5.37	-6.82	-6.89	-6.16	-6.77	-6.35	-6.61	-6.96	-6.38	-6.53	-6.77	-7.61	-5.70	-5.90
ipubs (with trend)	-2.15	-1.89	-1.94	-1.04	-1.74	-1.13	-1.20	-0.98	-1.90	-2.13	-2.28	-1.41	-1.38	-4.86	-1.31	-1.22
ipubs (no trend)	-1.47	-1.39	-1.28	-0.99	-1.16	-1.09	-1.12	-0.51	-1.40	-1.09	-1.57	-1.07	-0.36	-0.47	-1.09	-0.62
Dipubs	-1.78	-1.57	-1.67	-2.04	-1.57	-1.44	-1.75	-1.98	-1.66	-1.56	-1.77	-1.78	-1.92	-2.85	-1.76	-2.77
DDipubs	-6.32	-3.85	-4.09	-7.08	-3.92	-3.99	-7.19	-4.96	-3.99	-3.24	-2.73	-5.24	-7.89	-1.62	-4.49	-9.00
iprivs (with trend)	-3.03	-2.04	-2.56	-1.34	-1.68	-1.59	-1.71	-1.70	-1.70	-2.36	-1.71	-1.34	-1.54	-2.81	-1.50	-2.02
iprivs (no trend)	-2.62	-1.59	-1.93	-1.90	-1.56	-1.40	-1.64	-1.77	-1.41	-1.55	-1.27	-1.23	-1.40	-2.73	-1.19	-2.22
Diprivs	-4.26	-3.41	-4.08	-3.10	-3.32	-3.23	-3.51	-3.35	-317	-4.05	-3.13	-3.28	-3.15	-3.44	-3.79	-3.92
DDiprivs	-5.29	-5.29	-5.24	-7.98	-5.37	-7.54	-5.70	-7.13	-5.11	-5.30	-5.97	-5.12	-5.15	-5.74	-8.84	-7.19

Table 4.6. F-statistic for testing the weak exogeneity of country-specific foreign variables

Country	F test	95% Critical Values	Ys	ipubs	iprivs	poil
AT	F(2,60)	3.15	0.16	1.35	0.30	0.50
BE	F(1,61)	4.00	0.51	7.22*	0.76	1.84
DK	F(2,60)	3.15	0.27	8.07*	0.00	1.56
FI	F(2,60)	3.15	2.75	0.49	3.88*	0.62
FR	F(2,60)	3.15	0.88	1.02	3.49*	0.64
DE	F(2,60)	3.15	1.55	3.10	0.18	0.37
GR	F(1,61)	4.00	2.00	10.33*	1.96	0.19
IE	F(3,59)	2.76	1.45	8.25*	0.64	2.46*
IT	F(1,61)	4.00	4.06*	0.82	1.75	0.56
NL	F(1,61)	4.00	1.80	1.39	0.40	3.83
PT	F(3,59)	2.76	1.74	2.92*	0.52	0.22
ES	F(2,60)	3.15	1.19	0.97	2.00	3.85*
SE	F(1,61)	4.00	0.24	0.20	0.57	0.46
UK	F(0,62)					
US	F(3,59)	2.76	1.11	11.05*	0.81	
JP	F(1,61)	4.00	1.32	10.57*	0.72	0.14

* Denotes statistical significance at 5%

Table 4.7. Contemporaneous effects of foreign variables on their country-specific counterparts

Country	Domestic Variables		
	y	Ipub	ipriv
AT	0.31	-0.53	0.78
	[1.63]	[-1.69]	[2.89]
BE	0.36	-0.23	0.07
	[3.03]	[-1.78]	[0.46]
DK	0.35	0.85	0.30
	[1.35]	[4.21]	[0.86]
FI	0.84	-0.04	-0.03
	[3.03]	[-0.33]	[-0.10]
FR	0.60	0.12	0.28
	[7.57]	[1.63]	[3.19]
DE	0.88	0.58	0.78
	[3.90]	[9.36]	[3.46]
GR	1.18	2.19	-1.61
	[2.57]	[7.41]	[-1.849
IE	1.98	0.40	-0.40
	[3.06]	[2.17]	[-0.76]
IT	0.98	0.10	-0.01
	[6.84]	[0.38]	[-0.07]
NL	1.03	1.10	0.48
	[1.42]	[9.13]	[1.21]
PT	0.18	-0.67	0.54
	[0.46]	[-1.32]	[1.56]
ES	0.11	0.64	0.74
	[0.52]	[2.45]	[3.55]
SE	-0.15	0.16	1.48
	[-0.49]	[1.75]	[4.18]
UK	0.65	2.30	0.52
	[2.29]	[2.70]	[1.18]
US	0.06	0.22	0.63
	[0.22]	[5.28]	[3.23]
JP	0.26	0.01	0.16
	[1.31]	[0.53]	[1.76]

White´s hereroscedastic-robust *t*-ratios are given in square brackets.

Table 4.8 Number of cointegration relationships in the individual VARX* models

Country	# Cointegrating relations
AT	2
BE	1
DK	2
FI	2
FR	2
DE	2
GR	2
IE	2
IT	1
NL	1
PT	2
ES	2
SE	1
UK	1
US	3
JP	1

Figure 4.13. GIRF of Oil Price to a 1 s.e. positive shock to Germany's Public Investment

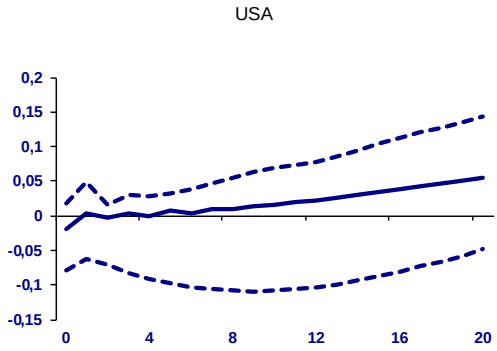


Figure 4.14. GIRF of Oil Price to a 1 s.e. positive shock to Portugal's Public Investment

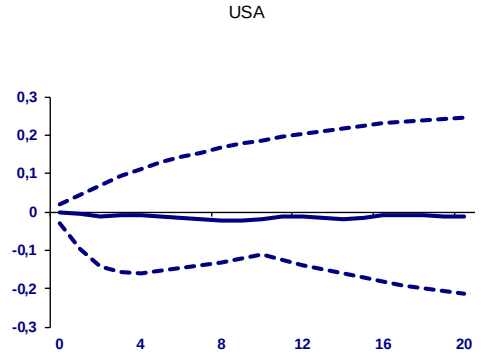


Figure 4.15. GIRF of Oil Price to a 1 s.e. positive shock to Germany's Private Investment

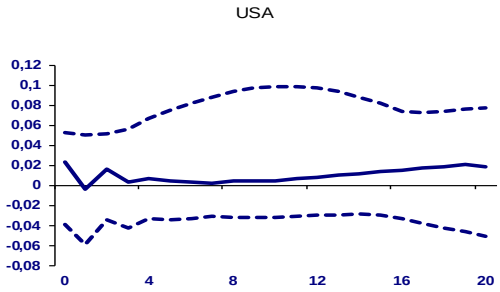
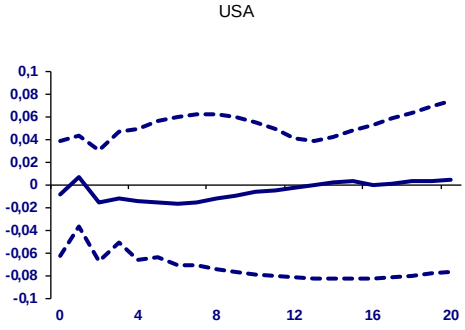


Figure 4.16. GIRF of Oil Price to a 1 s.e. positive shock to Portugal's Private Investment



Chapter 5

Concluding remarks

This dissertation deepens the understanding about what role public intervention, through PPPs, public consumption, and public investment, can play to encourage economic activity and also to check which is the most efficient, from an economic point of view: public sector or private sector. In fact, in an economic environment such as the European Monetary Union (EMU), in which fiscal policy is the only instrument that governments have to offset idiosyncratic shocks, it is crucial to determine the capacity of the public sector to influence the economic activity of a country. The fact that the recovery of the euro area over the last decade has been slow, weak, and uneven invites us to question if countries that present a current account surplus, such as Germany, can contribute in a more explicit way to the recovery of the European economy.

To investigate these questions we used three different econometric methodologies: a VAR, a panel VAR, and a GVAR. In chapter 2, a VAR model with four variables: public investment, private investment, PPP investment, and GDP was applied to test the macroeconomic impact of investment in public-private partnerships, and public and private investment in Portugal. Annual data from 1998 to 2013 were used only for the Portuguese economy. The results show us that investment in PPP leads to a crowding-out effect in both private and public investment and has a negative impact on GDP. In fact, the partial rate of return of an investment in PPP is negative, while the total rate of return associated with investment in PPP cannot be calculated since the accumulated gross growth rate over 20 years is negative. Public investment presents a crowding-in effect in private investment and in investment in PPP. In fact, in the presence of a positive shock in public investment, the impulse response functions show a positive initial impact in investment in both PPP and GDP. The output elasticity of public investment is positive. The partial rate of return of public

investment is greater than its total rate of return due to the fact that in the presence of a shock in public investment the response from the private investment and investment in PPP leads to an increase in output. Finally, private investment crowds-in both in investment in PPP and in public investment. The output elasticity of private investment is positive. The partial rate of return of private investment is higher than its total rate of return taking into account that the response of both public investment and investment in PPP to a shock in public investment is positive. The results that point to the existence of crowding-out in private and public investment as a consequence of investment in PPP, together with a negative partial rate of return of PPPs, are evidence that investment in PPP in Portugal, which involved almost exclusively the construction and operation of road infrastructures, is not the most efficient method of financing this kind of investment and/or have facilitated the expansion of road infrastructures beyond the social optimum. In fact, the investment through PPPs does not appear to be the kind of investment leading to the higher productivity that the Portuguese economy needs for a sustained increase in its export capacity or to allow for the correction of the accumulated external imbalances. Empirical results also support the belief that this kind of investment has undermined the capacity of private agents and the public sector to carry out their investment activities.

In the third chapter we went beyond the behavior of the Portuguese economy, and focused our attention on the response of the average GDP to innovations on public consumption, public investment, and private investment in two groups of European countries: “peripheral countries” and “core countries”. The 14 countries under analysis were divided according to their ability to refinance their government debt or to bail out over-indebted banks on their own, as a result of the recent economic crisis. The first group was composed of Greece, Ireland, Italy, Portugal, and Spain; the second group was composed of Austria, Belgium, Denmark, Finland, France, Germany, Netherlands, Sweden, and the United Kingdom. We also checked for crowding-out effects and crowding-in effects. Annual data were used instead of quarterly observations. The rationale for the use of annual data instead of quarterly data is the fact that there is no quarterly calendar for fiscal policy, and for that reason shocks identified with annual data may be closer to the actual shocks. The main drawback of annual data is the exclusion of within-year responses to shocks and also the fact that fewer observations are available. Due to this and in order to increase the precision of our estimates a panel VAR data was used. As mentioned above, the panel VAR approach allows for unobserved individual heterogeneity, adding a cross-sectional dimension to the model. The major disadvantage in using a panel VAR technique is that one cannot check

for the effects in each country on its own, but only an average effect on a certain group of countries.

It was not possible to compare the results of a shock in public and private sector for the Portuguese economy. Based on the results from Impulse Response Functions and Variance Decomposition, we found evidence that in the case of the "peripheral countries" the optimal measure to boost the economy is to raise public consumption or private investment, as in both cases GDP will tend to increase and one will find crowding-in effects. On the contrary, an innovation to public investment does not seem to be efficient, as GDP does not respond to it and one finds a crowding-out effect on private investment. As for the "core countries", the most adequate way to improve economic growth seems to be an increase in private investment, as GDP does not respond at all to a shock to public consumption or to public investment.

It is then clear from our analysis that countries do not react in the same way to shocks to public consumption, public investment, and private investment. In fact, public consumption plays an active role only in those economies that suffered severe economic consequences in the recent crisis. Private investment allows a push in the output of both the "peripheral countries" and the "core countries". Portugal, the country analyzed in chapter 2, belongs to the "peripheral countries" group. In line with the results found in chapter 2, we find that in the "peripheral countries" group, on average, a crowding-in effect from a shock to private investment prevails. However, in chapter 2 a shock in Portuguese public investment crowds-in PPP investment and private investment, while in the case of chapter 3, a shock to the public investment on the group of countries to which Portugal belongs seems, on average, to crowd-out private investment. Finally, if one takes into account all 14 countries in this analysis, the most efficient way to influence the economic performance of the group "all countries" is an increase in public consumption or in private investment, as GDP does not respond in a statistically significant way to a shock to public investment.

Finally, in the fourth chapter, using a GVAR approach and in particular GIRFs, we investigate the existence of cross-country spillover effects of an innovation in public and private investment in 16 countries. In the context of the European Monetary Union, we sought to understand if a country that shows a current account surplus can help economies that present severe difficulties to recover from the recent crisis. Namely, we quantified the impact of these innovations in a central European economy (Germany) and in a peripheral one (Portugal) on the majority of the European countries, USA, and Japan. Quarterly data from

1997Q1 to 2014Q4 were used for the 16 countries. Foreign-specific variables were constructed using trade-based weights that were fixed over time and computed using the average of exports' and imports' cross-country data, for the period 1999-2014. The main advantage in using a GVAR instead of a VAR or a panel VAR is that it allows for a range of different interdependencies between variables and countries, such as theory consistent long-run relationships, short-run spillover effects, or cross-sectional dependence in the error structure, offering a fair degree of flexibility in modeling business-cycle dynamics of the world economy in a coherent fashion. In opposition to what happens in a VAR or a panel VAR, in which IRFs calculated using different orders of variables will cause a different shape of the IRFs, the use of GIRFs overcomes the problem related with the ordering of the variables used in the model. On the other hand, certain restrictions have to be imposed in a GVAR technology that are not present in a VAR or a panel VAR, namely the use of the trade-based weight matrix. Moreover, as a considerable number of countries and variables entered the GVAR, quarterly data had to be used instead of annual data, with the main drawbacks pointed out above.

Our findings suggest a positive response in almost all countries' GDP to a public investment shock in Germany. However, these increases do not achieve statistical significance, not even in Germany itself. Private investment reacts negatively and immediately after this shock in Austria and Belgium. In Germany one finds evidence of a crowding-in effect, as the reaction of private investment is positive. However, once more, it is not statistically significant, which is also the case for the remaining countries. After a shock to public investment in Germany, public investment increases in neighboring countries such as Austria, Netherlands, and Sweden. On the contrary, a stimulus in Germany's public investment has a negative impact on Portuguese public investment, but only in the quarter immediately following the shock. Concerning a similar shock, but this time in a small open economy such as Portugal, GDP, as expected, does not react in a statistically significant way in any foreign country and also not in Portugal itself. Regarding private investment, it does respond positively and in a statistically significant way in Portugal only, pointing to a crowding-in effect in this economy, at least in the short run.

This same crowding-in effect in the Portuguese private investment after an impulse in public investment was found in chapter 2. On the contrary, in chapter 3 the average private investment of the group of five economies to which Portugal belongs reacts negatively to a shock on public investment, pointing to a crowding-out effect. Public investment reacts in a

negative way in the first quarter immediately after the shock in Germany and Belgium, decreasing also in France in the first three quarters after the impulse. On the contrary, it shows a positive impact in Spanish and Portuguese public investment.

Now looking at the results from an innovation in Germany's private investment, GDP does not reacting in a statistically significant way. Germany's private investment positive innovations do not seem to impinge significantly on other countries' private investment, except in the case of neighboring economies, namely Netherlands and Sweden, and Germany itself. A one standard error impulse in Portuguese private investment does not seem to significantly stimulate GDP in any of the economies considered, as one might expect from a small open economy. This shock shows a positive impact in Portuguese public investment, pointing also to a crowding-in effect. This same crowding-in effect was found in the studies presented in both chapter 2 and chapter 3 of this dissertation. Overall, even if Germany increases its public investment, it will not have the desired positive impact on peripheral economies. In fact, we find statistically significant cross-border effects mainly in neighboring countries, with the magnitude of the impacts being modest.

We perceive some natural extensions of the present dissertation. First, it would be fruitful to investigate the impacts of a decomposition of both private and public investment into the several categories that compose them instead of using them as a whole, as we did. It would also be of interest to analyze the impact on the investment's profitability of the types of shocks studied in this dissertation, as well as the impacts on investment short-run demand side effect and the investment long-run supply side effects. Another natural extension of this work would be to question the impact of an investment shock not only on GDP, as we did, but also on the labor market, namely changes in the qualification of labor and also possible migrants' movements due to an increase in investment in a certain country. It would be important to understand, in the European context, the extent to which a boost in the economic activity of center European economies can lead to a brain drain in the peripheral European countries. Another topic that may deserve further attention is the impact on the sustainability of public accounts as a result of an increase in public consumption or public investment. Finally, it would also be interesting to examine how an increase in public investment impacts the structure of the economy, i.e., what role can public investment have in the allocation of investment in a certain country.

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